STRATEGIES TO OPTIMIZE CONFINEMENT FED BEEF CATTLE IN THE NORTHERN PLAINS

BY

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

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ABSTRACT

STRATEGIES TO OPTIMIZE CONFINEMENT FED BEEF CATTLE IN THE NORTHERN PLAINS

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The goal of this dissertation was to understand the strategies needed to optimize performance of confinement fed beef cattle in the Northern Plains. This was accomplished through three objectives: 1) evaluate health, growth performance, and antibody titers in previously vaccinated, newly weaned calves administered a respiratory and clostridia vaccine upon arrival compared to no vaccination; 2) determine the influence of manger space restriction on program-fed feedlot heifers during the growing phase; and 3) to evaluate growth performance and carcass traits following transit of feedlot heifers sourced and finished in different regions of the United States. For objective 1, single-sourced, newly weaned steers [n = 70; initial body weight (BW) = 254±5.9 kg] were blocked by BW in a randomized complete block design (RCBD) of VAC (vaccinated for respiratory and clostridial diseases upon arrival) or NOVAC (not vaccinated upon arrival). Timing of vaccine administration did not appreciably influence 42-d growth performance and vaccinated calves had increased antibody titer response. For objective 2, Charolais × Angus heifers (initial BW = 329±22.1 kg) were used in a 109-d backgrounding study. Heifers were blocked by BW in a RCBD into one of two treatments: 20.3 cm (8IN) or 40.6 cm (16IN) of linear bunk space/heifer. Restricting manger space allocation from 40.6 cm to 20.3 cm did not negatively influence gain efficiency or the efficiency of energy utilization in heifers program fed a concentrate-based diet to gain 1.36 kg daily. For objective 3, yearling heifers (n = 190; initial BW 483 and 425 kg for SD and TX sourced, respectively) were used in a 2×2 factorial arrangement of origin state (SD vs TX) and finishing state (SD vs TX). Heifers transported to higher ambient temperatures had improved yield grades, but had reduced dry matter intake, quality grades and limited growth recovery. Heifers transported to lower ambient temperatures recovered growth and had improved quality grades at the same level of rib fat but had reduced yield grades. Collectively, these results indicate the management of cattle influences growth performance and that there are multiple ways to manipulate performance based on management decisions in each beef cattle sector.

CHAPTER I: Review of Literature

Introduction

The beef industry is unique in its design because of its segmented nature. In general, the beef industry can be divided into three classical sectors including the cow-calf sector, stocker/backgrounder sector, and feedlot sector (NASEM, 2016). However, each of these sectors can be further subdivided based on the producer's intentions for the cattle herd. The cow-calf sector includes both cattle intended for breeding (purebred/ seedstock) and commercial (crossbred) production. The stocker/backgrounder sector includes both breeding and commercial cattle, but with more emphasis on commercial cattle destined for the feedlot sector. The feedlot sector includes cattle intended for harvest. The segmented nature and variation within each of the classical sectors, introduces multiple components of increased or intensified management to attain optimal performance of cattle within each of these sectors. There is a body of evidence discussed in this review that has suggested that the management in the cow-calf sector influences production in both the stocker/backgrounder and feedlot sectors, in addition to the management in the stocker/backgrounder sector influencing production in the feedlot sector.

There are a multitude of factors that can influence cattle intended for both reproductive and terminal production. However, the purpose of this review is to focus on how these factors influence cattle intended for terminal production. Specifically, this review will discuss the strategies needed to optimize performance of confinement fed beef cattle in the Northern Plains based on 1) understanding the influence of timing of vaccination administration in newly weaned calves, 2) observing the effects of manger space restriction in program fed heifers during the backgrounding phase, and 3) evaluating how transportation of cattle to geographical regions different from their source of origin impacts growth performance and carcass characteristics.

Vaccine Administration

Vaccine administration is oftentimes initiated while beef calves are still within the cow-calf sector Dewell and Gorden (2016). Due to the segmented characteristic of the beef industry, prevention of disease can become quite challenging (Richeson et al., 2019). A common goal of vaccination programs is to protect calves against bovine rhinotracheitis (IBR), bovine virus diarrhea (BVD) I and II, parainfluenza (PI_3), and bovine respiratory syncytial virus (BRSV), in addition to clostridial pathogens such as *Clostridium chauvoei, C. septicum, C. novyi, C. sordelli, C. perfringens* Types C and D, and *Haemophilus somnus* (Dewell and Gorden, 2016). These viruses have been suggested to be associated with the Bovine Respiratory Disease (BRD) Complex (Boyles et al., 2003). Vaccination for these diseases is key as prevention of disease in beef cattle is crucial to allow cattle to achieve optimum performance in each industry sector. BRD is the most costly disease in the beef industry and is the leading cause of morbidity and mortality in beef cattle in United State feedlots (Griffin, 1997). Beef cattle often become more susceptible to diseases, such as BRD, when their immune system is compromised. Calves can become immunocompromised depending on a variety of factors that can cause stress to the animal and trigger a biological response. In addition to a compromised immune system, biological responses that can occur include transient endocrine responses, altered protein and energy responses, fluctuations in appetite and growth, and compromised digestion and rumen function (Loerch and Fluharty, 1999). Thus, the management of beef calves in the cow-calf sector can greatly influence their initial performance when being transitioned into the stocker/backgrounder sector.

Some of the common stressors that most beef calves will experience include weaning, transportation, deprivation of water and feed during transportation, novel feed ingredients and water systems, variable environmental conditions upon feedlot entry, and processing at the feedlot (Duff and Galyean, 2007). These in combination with increased vocalization that often accompanies the weaning event due to social separation from the calf’s dam (Haley et al., 2005), have been suggested to irritate the respiratory tract and increase the susceptibility to disease because of a weakened immune system. The consequences of these events may be exacerbated depending on the degree of stressors an animal experiences (Loerch and Fluharty, 1999).

As calves are transitioned into the stocker/backgrounder segment, vaccination protocols can vary. Vaccination against viral and bacterial pathogens that lead to BRD and other diseases have been proven to be an effective means to control disease. However, there is a body of evidence that suggests respiratory vaccinations are not as effective in immunocompromised peri-weaned calves (Arthington et al., 2013; Rodrigues et al., 2015; Richeson et al., 2019). This further supports what was concluded in a study by Callan (2001), that there is no single correct vaccination protocol and programs should be adjusted to specific producer needs. Vaccination protocols can vary depending on different characteristics such as size of operation, management practices, facility capabilities, and the type of cattle residing in each geographical location. Cattle in the Northern Plains commonly receive vaccinations at turn out to pasture, preconditioning (approximately 30 d prior to the weaning event), and at some point during the transition to the stocker/backgrounder sector, which may be upon arrival or delayed to a 14 to 30 d (Dewell and Gorden, 2016). This has proven to be an effective means to help allow calves to develop their immune systems prior to the anticipated exposure to stressors and pathogens that are commonly observed during the weaning event (Step et al., 2009). In fact, the administration of at least one viral vaccination following weaning but prior to shipment in the cow-calf sector from 1995 to 2005 increased from 55 to 95 percent (King et al., 2006). This was largely influenced by the increase in sale price of calves at the auction market because of the incorporation of certified health programs into operations. It was concluded that favorable experiences in the feedlot sector were observed when cattle buyers purchased calves that had been previously vaccinated which resulted in less incidence of morbidity and mortality.

Regardless of vaccine management systems prior to feedlot entry, calves respond differently to the stressors associated with weaning. Knowing the prior vaccine management history is important to consider when receiving cattle into a yard to determine effective timing of vaccination. Previous research has indicated that having appropriate preconditioning strategies plays a key role into decreasing morbidity rates associated with BRD (Step et al., 2009) and may influence the timing of vaccine administration. It has been suggested to delay vaccination of high-risk calves until 14 to 30 d after feedlot arrival to improve health and performance (Richeson et al., 2008; Griffin et al., 2018). This delay is proposed to allow the calf immune system sufficient time to recover from the stress of the weaning event and have a positive response to vaccination. There is limited research aimed at determining proper vaccination timing protocols for calves that have already received a vaccination before coming into a yard and are directly marketed and shipped from the ranch to the receiving yard without coming through an auction facility. Further investigation is required to better understand how prior management can influence growth in receiving calves. Proper vaccination protocols should be recommended based on what is ideal for the producer, location, specific phase of production, and management practices (Callan, 2001). Being cognizant of these factors will allow for optimization of cattle performance in this phase of production. It is important to note that vaccination programs are not substitutes for proper nutrition and management protocols (Dewell and Gorden, 2016). Thus, other factors relating specifically to the stocker/ backgrounder and feedlot segments can also influence optimization of beef cattle growth.

Bunk Management

One of the most important factors to consider during the stocker/backgrounder segment is how to manage feed intake. Uniform day to day management is essential to ensure cattle remain on feed to optimize performance (Boyles et al., 2003). Having proper manger, or bunk, management helps to prevent digestive upset and acidosis, which can result in poor performance. Daily feed management can be monitored with a bunk calling system to determine feed allowance levels for the subsequent daily feeding to match the amount of feed delivered to the amount of feed the cattle can consume (Pritchard, 1993).

There are a couple variations in bunk calling systems that have been implemented in the beef industry. One method of monitoring intakes and feed allowances as stated by Boyles et al., (2003) includes a score of 0- when the bunk has been empty for more than 1 hour; a score of 0 indicates the bunk has been empty for less than 1 hour; a score of 0+ is when a few fines or clumps are left in the bunk; a score of 1- with a thin layer, 1 kernel deep left of feed in the bunk; a score of 1 with less than 1 inch of feed in the bunk; a score of 2 with less than 2 inches of feed in the bunk; and a score of 3 with less than 3 inches of feed in the bunk. In a method suggested by Pritchard (1993) a score of 0 indicates no feed remaining in the bunk; a score of ½ indicates scattered feed present with most of the bottom of the bunk exposed; a score of 1 indicates a thin uniform layer of feed across the bottom of the bunk, being approximately 1 kernel deep; a score of 2 indicates 25 to 50 percent of the previous feed remaining; a score of 3 indicates a crown of feed is thoroughly disturbed with 50 percent of feed remaining; and a score of 4 indicates feed is virtually untouched with the crown of feed still noticeable. Regardless of the system used, these bunk calling scales can act as tools to help reduce daily intake fluctuations and further prevent risk of acidosis (Pritchard, 1993; Boyles et al., 2003). The key component to these systems is consistency. While the consistency of these systems is especially important for cattle consuming maximal levels of intake, other methods can be used to help ensure consistent management and maximize the growth potential of cattle.

Feed Intake Management

Growth has been defined as the increase in dimension or accumulation of mass over time as an organism proceeds toward its chemical and cellular maturity (Pritchard, 1996). This growth can be manipulated based upon the amount and rate at which calories are offered to a beef animal (NASEM, 2016), as well as how efficient the beef animal is at converting those calories into the economically relevant tissues of muscle and adipose tissue (Smith and Johnson, 2020). Historically, backgrounding programs have been implemented in an attempt to "frame" or "straighten" out terminal cattle to better prepare them for a finishing system. In recent years, feed intake management systems have been used as a growth management tool to target desired rates of gain to optimize the growth of cattle in the stocker/backgrounding phase in combination with setting up the cattle to achieve compensatory growth in the finishing phase (Galyean et al., 1999).

As described by Owens et al., (1995), feed intake management systems have been used to slow rates of growth when high-forage rations or pasture systems are unavailable, avoid overconsumption or fluctuations in intake among cattle in the same pen, ease bunk management, decrease total manure outputs, identify sick cattle, step-up transition to *ad libitum* intake of high concentrate rations, and to improve feed efficiency. Reductions in total feed waste have also been noted as a component of overall feed efficiency (Galyean et al., 1999).

A primary goal of a stocker/backgrounder program is to suppress fat or lipid deposition and promote the growth of bones and lean tissue by achieving less-than-maximal growth (Block et al., 2001). This is done in efforts to prolong the growth curve of smaller-framed cattle to reach a more desirable mature weight when cattle are harvested at the end of the finishing period (Owens et al., 1993). It was also suggested by Owens et al., (1993) that while this shift in the growth curve is accompanied by increased days on feed, producers are consequently able to achieve more pounds of saleable product from the same animal at harvest compared to if the beef animal was not allowed a period focused on growth.

The management of feed intake plays a crucial role in prolonging the growth curve in cattle in the stocker/ backgrounder phase of production (Owens et al., 1993; Galyean et al., 1999). Daily feed intake is known to be directly correlated with beef cattle growth (NASEM, 2016). Feed intake can be represented by a few different strategies. Feed consumption at an *ad libitum* level describes where cattle are consuming feed at a maximal level that their body capacity or appetite allows (Galyean et al., 1999). Controlling or managing feed intake relative to the *ad libitum* amount is not a new concept to the cattle feeding industry. As further described by Galyean et al., (1999), feed intake can be managed via feed intake management systems such as restricted feeding or programmed feeding.

Limited or restricted feeding during the backgrounding phase would include management where feed intake is restricted relative to the actual or predicted *ad libitum* intake of a pen of cattle. The level of this type of restriction is assumed to be 75 to 80 percent of the *ad libitum* dry matter intake (DMI) that the cattle are expected to consume (Pritchard and Bruns, 2003). Restriction can either refer to the restriction of the actual amount of intake allowed to an animal or may refer to restricting the amount of specific nutrients to a beef animal. The restriction of feed relative to the *ad libitum* amount has shown positive influences on growth performance and carcass outcomes. The restriction of the amount of DMI allowed has led to improvements in feed efficiency (Hicks et al., 1990; Loerch and Fluharty, 1998) and ultimately resulted in reduced fat content of carcasses. Whereas restricting the energy content of the diet by increased amounts of roughage inclusion or by limiting the amount of a high-concentrate diet that is fed has also been suggested to manage growth rate during the backgrounding phase (Blom et al., 2022). However, the level of restriction should be considered to avoid a nutrient deficit, which could limit performance.

Program feeding refers to the use of net energy equations to calculate the specific quantity of feed required for net energy at maintenance at a desired daily rate of gain (Galyean et al., 1999). Body composition can be predicted by determining nutrient requirements to provide a basis for prediction of performance and overall carcass value (Fox and Black, 1984). The specific quantity of feed required is estimated to be approximately 5 to 10 percent less than the *ad libitum* DMI the cattle are expected to consume (Pritchard and Bruns, 2003). Program-fed cattle have been shown to be more feed efficient and consequently have decreased total feed required and feed costs per animal compared to *ad libitum* fed cattle (Loerch and Fluharty, 1998). The use of net energy equations from the California Net Energy System (CNES) has been proven to be an effective means of predicting expected growth measures in feedlot cattle (Zinn, 1989; Gunter et al., 1996; Loerch and Fluharty, 1998; Galyean et al., 1999). This system was developed to accurately determine and predict performance measures in live beef cattle (NASEM, 2016). In general, the equations set forth by the CNES is to determine the amount of daily intake needed by calculating the amount of feed required for daily maintenance plus the feed required for daily gain. Once these two amounts are calculated, the summation of these equations can be used to determine the amount of DMI needed for a beef animal to attain a desired daily gain. This provides producers and researchers with an accurate strategy of managing the feed offered to their cattle. The use of the CNES has been shown to be the most effective when tabular dietary net energy values of the feed ingredients for maintenance and gain and the expected mature final body weight of the cattle being fed are known (Zinn, 1989). Validity of this system may be hindered if the incorrect mature shrunk body weight is used, unaccounted for variation in physiological factors of the cattle (such as previous plane of nutrition, gut fill, anabolic implants), external factors affecting the requirement for energy maintenance, or fluctuation in feed ingredient composition (NASEM, 2016). These factors need to be accounted for and controlled to have accuracy in feed intake management.

Manger Space Management

Another growth management method to manage intake includes restricting the amount of linear manger or bunk space allowed per individual animal. As feed bunks represent a significant investment for cattle feeders (Kammel and Halfman, 2015), determining minimal amounts of linear bunk space needed per beef animal is crucial for producer profitability and maximizing beef cattle performance. The amount of linear manger space required varies depending upon the type of diet being fed, the size of cattle being fed, and the frequency of feed deliveries throughout the day (Boyer et al., 2021). A higher percentage of roughage in the diet requires more linear bunk space than a ration with a higher percentage of concentrate because of the bulkiness of the ration. Younger lighter weight cattle require more linear bunk space in relation to their body size as they generally consume high forage diets and prefer to eat together. Cattle fed once a day require more linear space than feeding two or more times a day as the total ration is delivered at one time. The Federation of Animal Science Societies (FASS, 2020) recommends when cattle of 180 to 380 kg are fed twice daily, that 22.9 to 27.9 cm of linear bunk space is provided, whereas 45.7 to 55.9 cm of linear bunk space is required when cattle are fed once daily. It is recommended when cattle of 360 to 545 kg are fed twice daily, that 27.9 to 33.0 cm of linear bunk space is provided, whereas 55.9 to 66.0 cm of linear bunk space is required when cattle are fed once daily (FASS, 2020). Reductions in linear space required are even greater as the frequency of daily feed deliveries is increased.

Cattle performance, welfare, and health are dependent upon bunk space and can be negatively impacted in cattle experiencing restriction (Harrison and Oltjen, 2021). Welfare and health concerns have been investigated in dairy cattle and have determined that when cattle are fed in reduced linear bunk space situations, increased standing, aggression and competition at the bunk were observed (Proudfoot et al., 2009; Greter et al., 2013; DeVries, 2019). These changes in behavior resulted in reduced intakes, feeding activity, and rumination activity with fewer, larger, and longer meals. It has also been suggested that restricting manger space allowed per animal in dairy cattle may be further restricted as the animal body capacity increases with age (DeVries, 2019). It is recommended that 30 to 45 cm of linear space is required for dairy cattle, but if all cattle are feeding at the bunk, this space doubles to allow cattle to fit along the bunk line because of space needed to fit their body capacity size (DeVries, 2019). This was suggested to induce additional social stress caused by dominant cattle and could pose concern for the more timid cattle that are not as aggressive in their feeding behavior. Therefore, not all animals may be able to eat at a single time and multiple feedings may be required, or decreasing pen stocking density may be required if there appears to be significant issues with not all cattle being able to eat. This may be even more apparent when cattle are offered predominantly forage rations, such as the diets fed to dairy cattle, mature beef cattle or newly weaned calves.

Reductions in linear bunk space have been investigated in beef cattle. Limiting bunk space is oftentimes studied in combination with restricted feeding or program feeding. This is largely because of the practical inability to fit a full-size ration within a limited amount of bunk space. Allotments of 24.3 to 63.5 cm of linear bunk space per animal were recommended when DMI was limited in order to observe reductions in performance

(Duncan et al., 2022). Bunk space allotments of 15 to 45 cm linear space per animal did not negatively influence growth performance measures in steers that were limit-fed during the receiving phase (Zinn, 1989). Lake (1986) also observed no differences in performance in heifers that were limit-fed twice daily with 23 or 30 cm of linear bunk space. When steers were fed twice daily with 20 cm or 87 cm of linear space, DMI, average daily gain (ADG), and feed efficiency were not affected (Harrison and Oltjen, 2021). A few studies have evaluated the use net energy equations to predict expected growth values in combination with program fed cattle given limited bunk space. Zinn (1989) was able to program feed intake to allow for a desired rate of gain with linear bunk space allotments ranging from 15 to 60 cm. Gunter et al., (1996) was also able to achieve a desired gain during the growing period with restricted amounts of bunk space (12.7, 20.3, 27.9, or 35.6 cm of linear space). No negative performance influences were observed in program fed cattle with limited bunk space in either of these studies. Additional investigation into the combination of feed intake management systems and linear bunk space management could expose new ways to optimize overall feed management.

Previous Plane of Nutrition

During the stocker/ backgrounder phase, producers feed less expensive feedstuffs to cattle while still maintaining adequate rates of gain to focus on lean tissue and frame growth (NASEM, 2016). Variations in nutrition during this sector have been shown to influence rates of growth during the subsequent finishing phase. As discussed above, daily feed intakes restricted while cattle are in a backgrounding system can help achieve this growth management goal by allowing cattle to gain an expected amount. The underlying mechanism involved with rates of growth is the rate of cell maturation during this time

(Pritchard, 1996). It is suggested that the rate at which cells mature is not accelerated by the intake of additional calories but is rather influenced by the type of calories consumed prior to cellular maturity. In whole body growth, there is a prioritization of how nutrients are partitioned towards the growth and development of each bodily tissue (Wilson and Osbourn, 1960). Nutrient partitioning goes towards tissues of highest to lowest priority starting with the central nervous system, skeletal and connective tissue, visceral organs, skeletal muscle, and finally adipose tissue. Although skeletal muscle growth is of primary interest in feedlot cattle, growth also includes the amount of adipose tissue deposited (Owens et al., 1993). Therefore, allowing the growing beef animal to gradually deposit fat is an essential component of normal growth. As stated by Pritchard (1996), beef females require adequate adipose tissue levels in order to attain puberty and maintain reproductive function. Traditionally, beef females intended for reproductive replacement are estimated to be at 60 to 65 percent of mature body weight at time of breeding (Day and Nogueira, 2013). It was suggested by Pritchard (1996) that managing the growth rates of beef cattle intended for slaughter to achieve a similar percentage of body weight as that at puberty during the stocker/backgrounder phase prior to feedlot sector entry could prove to be a useful target for growth. This would provide producers with an additional way to optimize their nutritional strategies to reach this target during this phase of production.

In a growing beef animal, energy intake above the energy needed for maintenance of normal bodily processes can vary greatly depending on the type of diet that is fed (NASEM, 2016). Thus, the type of calories consumed, dependent upon the energy available within those calories greatly influences the nutrient flow to tissues as they develop towards cellular maturity in the subsequent growth phase. Cattle growth and performance during the stocker/ backgrounder segment is partially dependent upon the type of feed ingredients offered during this time (Boyles et al., 2003). Common feedstuffs offered during this phase of production include predominately forage or roughage-based rations. These include both pasture-based systems and large portions of hays and silages (20 to 30 percent) fed to cattle while in a dry lot setting (NASEM, 2016). Other diets that may be offered during stocker/ backgrounding phase, most commonly in a dry lot setting, include limited high concentrate diets (12 to 20 percent of the diet containing roughage-based feedstuffs). Each of these systems essentially aim to accomplish the same goal by providing sufficient energy and nutrient profile for growth without providing these in excess to avoid both inefficient growth and added cost.

The biggest impact the previous plane of nutrition can have on cattle can be measured by the magnitude of gain the cattle have in the next phase of production. This period of growth can be referred to as compensatory growth. Compensatory growth has been defined as a period of faster or more efficient rate of growth following a period of slower or less efficient rate of growth that could result from nutritional or environmental stress of planned management strategies (NASEM, 2016). The degree of change during the period of re-alimentation is highly dependent on variation in severity and duration of restriction, nutritional regimen during that period, the interval of measurement between periods, and the genotype of the cattle. A severe enough restriction to reduce energy requirements for maintenance during the stocker/backgrounder phase could result in an enhanced increase in the available energy for gain in the subsequent phase (Drouillard et al., 1991; Pritchard, 1996).

Fox et al., (1972) indicated that steers near a zero energy balance were able to compensate growth during the subsequent period when offered a high energy diet. During the initial days on a high energy diet, steers had a greater portion of muscle tissue gain followed by increased portions of adipose tissue gain at the end of the high energy ration period compared to cattle that did not receive energy restriction during the growing phase. This phenomenon is described by Pritchard (1996) as a dramatic increase in the energy available for gain caused by increased intake in the period following the restriction, thus allowing for more efficient use of energy consumed. Another component to compensatory growth is simply the increase in gastrointestinal tract fill (NASEM, 2016). Restricted animals may have reductions in gastrointestinal tract fill that can be accounted for by adjusting body weight by two percent, whereas the gastrointestinal tract fill in non-restricted cattle can be accounted for by adjusting body weight by four percent (Zinn, 1989). Cattle grazing on pasture may experience a greater magnitude of compensatory growth compared to cattle limit-fed rations in a dry lot setting as there is a greater capacity of gastrointestinal tract to fill in addition to an abundance of intake calories allowing for a dramatic increase in gain (Zinn, 1989; Owens et al., 1993; Pritchard, 1996). Thus, accounting for the previous plane of nutrition plays a key role in accounting for the initial performance following the stocker/backgrounder segment.

Transportation of Cattle

While there are multiple factors that need consideration prior to and throughout the time in a feedlot setting, events that transpire during the transitionary time should also not be overlooked. Because of the segmented nature of the beef industry, beef cattle intended for harvest are procured from all regions of the United States to ultimately be finished in a feedlot. Deters and Hansen (2020) concluded that there are at least four times, if not more, when a beef animal intended for harvest may be transported in its lifetime. These events include from the birthplace to an auction facility, auction facility to a stocker or backgrounder operation, stocker or backgrounder operation to a feedlot, and a feedlot to a harvest facility. According to the data collected by the 2016 National Beef Quality Audit, the average distance traveled for fed cattle to a harvest facility was 455.7 km with an average transit time of 6.7 h (Harris et al., 2017). The minimum and maximum distance and transit times were 3.2 to 2,273.8 km and 0.2 to 39.5 h, respectively. It is important to note that this encompasses only one of the many trips that a beef animal could experience in their lifetime. Although transportation time represents only a fraction of a beef animal's lifetime, these events do impose stress that could affect performance and carcass outcomes.

Transportation of cattle induces stress and can lead to heightened immune responses, especially when cattle are transported for a long period of time (Arthington et al., 2003; Deters and Hansen, 2020). This increase in stress is largely caused by deprivation of water and feed resources but could be further exacerbated with increased noise, possible overcrowding, and poor air quality and movement (Loerch and Fluharty, 1999). As previously mentioned, gastrointestinal tract fill can vary based on the previous plane of nutrition. Cattle coming from a pasture-based system have large gastrointestinal tract fill compared to cattle in a limit-fed setting (Zinn, 1989). Therefore, the effect of the previous plane of nutrition may dramatically increase the shrink loss due to transportation, simply because there are more intestinal contents that can be excreted during this time (Coffey et al., 2001).

Transported cattle have been reported to have slower overall growth following transit (Pritchard and Preston, 1992). This has been referred to as recovered growth. The amount of growth that must be accounted for is largely dependent upon the characteristics of the cattle prior to shipping, as well as the management of the cattle upon receiving. Still, the degree for which growth needs to be recovered is also influenced by the duration of the transit event. As reported by Self and Gay (1972), cattle transported an average of 1023 km would have approximately 7.2 to 9.1 percent shrink due to transit. The amount of shrink was similar between cattle regardless of age. Cattle that were shipped directly from their birthplace to a stocker or backgrounder operation had less shrink compared to cattle that were shipped from an auction facility to a stocker or backgrounder operation (7.2 vs 9.1%, respectively). Cattle purchased from ranches and shipped to a finishing facility also had less shrink during fall months compared to summer months (6.4 vs 8.3%, respectively). This data was pooled and it was determined that cattle required approximately 10 d to recover the shrink lost due to transportation (Self and Gay, 1972). However, longer days on feed (approximately 30 d) were required when cattle accrued greater than the average amount of transit shrink. Practices that have been suggested to help reduce the insult of the transportation event and reestablish gastrointestinal tract function include providing *ad libitum* water and grass hay following transit (NASEM, 2016; Self and Gay, 1972). This is especially important with young calves that are transported long distances.

Texas is the largest producer of the calf crop in the United States, while South Dakota ranks 5th for production of the calf crop (Wisevoter, 2023). A majority of the feedlots in the United States are located in the southern high plains region, which includes areas of the panhandle of Texas up to western Kansas. A majority of cattle finished in these feedlots are sourced within the region. However, there are still a number of calves that come from outside of the region, some of which come from the northern plains, such as cattle sourced from South Dakota. Cattle performance can be dictated and influenced by a variety of factors. Stressed cattle oftentimes have reduced performance compared to cattle that are not experiencing stress (Duff and Galyean, 2007). These incidences of stress can be caused by a variety of factors (weaning, handling, dust, off-feed and water, climate, transportation, etc), and should be avoided if possible. The transportation of cattle from one region to another can also cause stress to cattle because they must adapt to the climate of that region. However, transportation of cattle to feedlots and the climates of regions where these feedlots are located cannot be avoided but requires some consideration.

Geographic Region

Weather between regions can be drastically different depending on the time of year. Cattle in the Northern Plains are generally finished under favorable climatic conditions (without extreme high or low ambient temperature loads), but as the total time cattle spend in a feedlot setting could be over half a year, there is opportunity for cattle to experience extreme ambient temperature at both spectrums (Gubbels et al., 2023). Environmental factors and whether cattle are fed in extreme low or high ambient temperatures could impact cattle performance and the competitiveness of feeding cattle between geographical regions (Pritchard and Preston, 1992). Heat stress (St-Pierre et al., 2003) and cold stress (Smerchek and Smith, 2020) have been reported to reduce livestock performance and well-being. A more in-depth analysis of ways to mitigate these temperature extremes have been reported elsewhere (Mader, 2003; Smerchek and Smith, 2020).

An important factor to consider is the degree at which temperatures are considered to be ambient for each region. The temperature humidity index (THI) value is often calculated to better characterize when cattle are experiencing ambient temperature loads. This is calculated using the following formula: THI = 0.81 × ambient temperature + [relative humidity × (ambient temperature - 14.40)] + 46.40 (Hahn, 1999a). A higher THI value has been shown to be positively correlated with incidence of heat stress (Mader, 2003). The Livestock Weather Safety Index (LCI, 1970) has further noted specific ranges of THI values where caution should be exercised. These classifications for heat stress include less than or equal to a THI value of 74 as normal; a THI value of greater than or equal to 75 but less than or equal to 78 as alert; a THI value greater than or equal to 79 and less than or equal to 83 as danger; and a THI value greater than or equal to 84 as emergency. Using THI values can help to verify if animals are experiencing high ambient temperature loads. The severity of high ambient temperatures may be more critical if cattle exposed to the these heat stress events are unable to achieve temperature cool-down during the nighttime where THI values fall below critical levels (Lockard et al., 2020).

While THI values can be a great tool for measuring incidences of heat stress, recent work in the dairy industry has indicated that the level of which increasing THI values become critical may be lower in high producing, more efficient dairy cattle compared to what was initially determined as critical because of increased fasting heat production (Zimbelman et al., 2009). Milk production was observed to start declining at THI values of 68 compared to initial threshold THI level of 72. As the beef industry continues to trend towards more efficient producing beef cattle, the THI levels that were once considered "normal" (THI ≤ 74) may be considered to be "alert" compared to the levels originally determined by the Livestock Weather Safety Index (75 ≤ THI ≥ 78). This in combination with the region of finishing may also require further investigation, as Gubbels et al., (2023) reported THI levels at or above 72 to be considered alert. THI values ranging between 70 and 74 for an extended period of time were also suggested to indicate periods of heat stress (Lockard et al., 2020). Thus, the degree to which region of finishing, season of finishing, and the characteristics of the cattle being finished during elevated ambient temperature could influence feedlot performance requires further interpretation.

Summary

Collectively, there are a multitude of factors that can influence how beef cattle intended for harvest will perform in the feedlot, from the cow-calf segment through the stocker/backgrounder and finishing segments. Cattle performance cannot always be specifically traced back to one sector but is rather influenced by each sector and phase of production. The management of cattle in each of these sectors is influential for each subsequent sector. While there are many management decisions that need to be considered, being aware of these practices is important for the optimization of beef cattle performance. While the aforementioned are factors that producers can generally be cognizant of, there are still unintended events producers may need to be prepared for. Knowing prior health practices of receiving cattle, having accurate nutrient administration during the stocker/ backgrounder phase, and proper management during adverse environmental conditions during the finishing phase can better help prepare producers in the incidence of adverse events. A general understanding of how these factors can affect beef production is crucial for producers in all sectors of the beef industry to ensure cattle reach their maximal potential. Therefore, to better comprehend the how these mechanisms influence the overall performance of beef cattle in the feedlot, the objectives of this dissertation are:

1. To evaluate the health, growth performance, and antibody titers to bovine rhinotracheitis (IBR), bovine virus diarrhea (BVD) I and II, parainfluenza (PI_3), and bovine respiratory syncytial virus (BRSV) in previously vaccinated, newly weaned calves administered a respiratory and clostridia vaccine upon arrival compared to receiving no vaccination upon arrival.
2. Determine the influence manger space restriction had on program-fed feedlot heifers during the growing phase.
3. To evaluate growth performance and carcass traits following transit of feedlot heifers sourced and finished in different regions of the United States.

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CHAPTER II: Effects of on-arrival application of a modified-live respiratory and clostridia vaccination on health measures, growth performance, and antibody titers of previously vaccinated newly weaned calves

ABSTRACT

The objective of this research was to evaluate health, growth performance, and antibody titers to bovine rhinotracheitis (IBR), bovine virus diarrhea (BVD) I and II, parainfluenza (PI_3), and bovine respiratory syncytial virus (BRSV) in previously vaccinated, newly weaned calves administered a respiratory and clostridia vaccine compared to no vaccination upon arrival. Single-sourced, newly weaned steers [n = 70; initial body weight (BW) = 254 ± 5.9 kg] were allotted to 10 pens (n = 5 pens/treatment with 7 steers/pen). Steers were blocked by BW in a RCBD and were assigned to one of two treatments: VAC (vaccinated for IBR, BVD 1 and 2, PI_3, and BRSV and clostridial species upon arrival) or NOVAC (not vaccinated upon arrival). Steers were individually weighed on d 0 (arrival), 1, 21, and 42 for growth performance measures. Whole blood samples were collected (n = 3 steers/pen closest to the pen mean BW) on d 1, 21, and 42 via jugular venipuncture for antibody titer responses. Depression scores of 0 (normal) to 4 (moribund) were recorded daily for each individual steer for 21 d. Body weight gain and feed efficiency were not influenced ($P \geq 0.50$) by treatment. Dry matter intake as a percentage of BW tended ($P = 0.07$) to increase by 3.5% for NOVAC compared to VAC. No treatment by day interactions ($P \geq 0.50$) were observed for depression scores or IBR, BRSV, BVD I and II or PI_3 titers. No treatment main effects were observed ($P \geq 0.50$) for titer concentrations or the proportion of positive samples for BVD I and II. However, VAC steers had increased ($P < 0.05$) titer concentrations and the proportion of positive samples for IBR, BRSV and

PI_3. Collectively, growth performance was unaffected by vaccination, and vaccinated calves had increased antibody titer responses, as expected.

INTRODUCTION

Bovine respiratory diseases (BRD) is the most costly disease and is the leading cause of morbidity and mortality in United State feedlots (Griffin, 1997). This is caused in part by the segmented characteristic of the beef industry, making prevention of disease more challenging (Richeson et al., 2019). Even though vaccination against viral and bacterial pathogens that lead to BRD has been proven to be an effective means to control disease, there is a body of evidence suggesting that respiratory vaccinations are not as effective in immunocompromised peri-weaned calves (Arthington et al., 2013; Rodrigues et al., 2015; Richeson et al., 2019).

Newly weaned calves commonly go through a variety of stressors, namely, transportation as well as feed and water deprivation during the initial 24 h post-weaning period (Arthington et al., 2008). The severity of these stressors (time off feed/water, transit time, weather, etc.) can influence the calf’s immune system. Another consideration is the prior management system that calves come from, which may differ in vaccination protocols. Ideally, prior vaccination should provide proper antibody titers to prevent diseases. Vaccination administration during preconditioning or backgrounding phases builds immunity in cattle prior to anticipated exposure to stressors and pathogens (Step et al., 2009). Thus, incorporating multiple vaccines prior to these anticipated events may better help prepare calves in times of immunological challenges.

Calves respond differently to the stressors applied at the time of weaning. Thus, knowing prior vaccine and management history is important to consider when receiving cattle into a feedyard to determine effective timing of vaccination. However, there is limited research in determining proper vaccination timing protocols for calves that have received a prior vaccination and are directly marketed and shipped from the ranch to the receiving feedyard without coming through auction facility. Therefore, the objective of this research was to evaluate health measures, growth performance, and antibody titers to infectious bovine rhinotracheitis (IBR), bovine virus diarrhea (BVD) I and II, parainfluenza (PI_3), and bovine respiratory syncytial virus (BRSV) in previously vaccinated, newly weaned calves administered a respiratory and clostridia vaccine on arrival or no administration of vaccinations upon arrival.

MATERIALS AND METHODS

Institutional Animal Care and Use Approval

This study was conducted at the Ruminant Nutrition Center in Brookings, SD between October and December 2021. The animal care and handling procedures used in this study were approved by the South Dakota State University Animal Care and Use Committee (2109-061E).

Cattle Management and Treatments

Charolais × Angus crossbred steers (n = 70; initial BW = 254 ± 5.9 kg) were used in a 42-d receiving phase study. Steers were procured from a ranch in western South Dakota where all steers were vaccinated against IBR, BVD types I and II, PI_3, and BRSV (Pyramid 5 Plus Presponse, Boehringer Ingelheim Animal Health, Duluth, GA); *Clostridium chauvoei*, *C. septicum, C. novyi*, *C. sordelli*, *C. perfringens* Types C and D, and *Haemophilus somnus* (Vision 7 Somnus with Spur, Merck Animal Health, Rahway, NJ); and treated against internal (Ivermectin Injection, Durvet Inc., Blue Springs, MO) and external parasites (Standgaurd, Elanco Animal Health, Greenfield, IN) approximately 30 d prior to the weaning event. On d -1, all steers were transported approximately 513 km to the Ruminant Nutrition Center in Brookings, SD. Steers were provided with long-stem grass hay in bunks the day of receiving. On d 0, steers were individually weighed (scale readability 0.454 kg) to determine an allotment BW. On d 1, steers were again weighed and assigned to 1 of 10 pens (n = 5 pens/treatment with 7 steers/pen) in a randomized complete block design (blocked by location) into two treatments: Vaccinated for: IBR, BVD I and II, PI_3, and BRSV (Bovi-Shield Gold 5, Zoetis, Parsippany, NJ) and clostridial species (Ultrabac 7/Somubac, Zoetis) upon arrival [VAC] or not vaccinated [NOVAC]. All steers were fed in small pipe and cable pens (7.62 m × 7.62 m concrete surface pens with 7.62 m of concrete bunk space) with automatic heated waters.

Dietary Management

Fresh feed was manufactured twice daily in a stationary mixer (2.35 m^3; scale readability 0.454 kg). The diet [Table 1; dry matter (DM) basis] consisted of ingredients common to the northern plains feeding region. Liquid supplement was included to provide monensin sodium (Rumensin 90; Elanco, Indianapolis, IN) at 27.5 g/kg (DM basis) and vitamins and trace minerals to meet nutrient requirements for growing and finishing beef cattle (NASEM, 2016). Diets presented in Table 1 are actual DM diet composition, plus tabular nutrient concentrations and energy values (Preston, 2016).

If carryover feed was present the following morning, orts were collected, weighed, and dried in a forced air oven at 100°C for 24 h to determine DM content. The DMI of each pen was adjusted to reflect the total DM delivered to each pen after subtracting the quantity of dry orts for each interim period. Weekly DM analysis (drying at 60°C until no weight change), tabular nutrient values (Preston, 2016), and corresponding feed batching records were used to determine actual diet formulation and composition. Additionally, weekly DM determination (method no. 935.29) was used to determine DM content of each ingredient fed each week (AOAC, 2012, 2016).

Depression Scores

Depression scores were ranked on a scale of: 0 = Normal, no signs of disease or depression; 1 = Noticeable depression, signs of weakness are usually not apparent, slower than pen mates but still perks up when approached and does not appear weak, actively follows your movements with a raised head; 2 = Marked depression, moderate signs of weakness may be apparent but without significantly altered gait, stands with head lowered, will perk up when approached but will return to depressed stance, moves slowly and falls towards back of group, may display signs of weakness such as incoordination; 3 = Severe depression accompanied by signs of weakness such as altered gait or lowered head, obviously very weak, difficulty in moving with group, raised head only when approached closely; or 4 = Moribund, unable to rise.

Antibody Titers

Whole blood samples (10 mL) were collected via jugular venipuncture from a subsample of steers (n = 3 steers/pen closest to the pen mean BW; the same 3 steers were used throughout the study duration) on d 1, 21, and 42 using an evacuated tube (Vacutainer tube) and a 16 ga × 3.81 cm needle to harvest sera for antibody titer responses. Depression scores (DS) were recorded from d 1 to 21 to determine clinical signs of BRD (Perino and Apley, 1998).

Growth Performance Calculations

Steers were individually weighed on d 0, 1, 21, and 42. Cumulative daily weight gain was based on initial BW (average of d 0 and 1 BW, no shrink applied) and final shrunk BW (a 4% pencil shrink was applied). Average daily gain (ADG) was calculated as the difference between final shrunk BW and initial BW, divided by the days on feed for the respective period. Feed efficiency, or the gain to feed ratio (G:F) was calculated by dividing ADG by dry matter intake (DMI). Dry matter intake as a percentage of BW was calculated from average BW divided by the average DMI for that period.

Dietary NE Utilization Calculations

Observed dietary net energy (NE) was calculated from daily energy gain (EG; Mcal/d) according to the medium frame steer calf equation using mean equivalent BW [median feeding BW × (478/534)]: EG, Mcal/d = $ADG^{1.097} \times 0.0557W^{0.75}$; energy gain was the daily deposited energy and W was the mean equivalent BW (NRC, 1996). Maintenance energy required (EM; Mcal/d) was calculated by the following equation: EM, Mcal/d = $0.077BW^{0.75}$ (Lofgreen and Garrett, 1968; NASEM, 2016) where BW was the average of initial shrunk BW and final shrunk BW (initial BW shrunk 4% and final BW shrunk 2%). Using the estimates required for maintenance and gain, the observed dietary NEm and NEg values of the diet were generated using the quadratic formula: $x = \frac{-b \pm \sqrt{b^2 - 4ac}}{2c}$, where x = NE_m, Mcal/kg, a = -0.41EM, b = 0.877EM + 0.41DMI + EG, c = -0.877DMI, and NE_g was determined from: 0.877 NE_m – 0.41 (Zinn and Shen, 1998; Zinn et al., 2008a). The ratio of observed-to-expected NE ratio was determined from observed dietary NE for maintenance or gain divided by tabular NE for maintenance or gain. To calculate predictive values, a final body weight of 665 kg was assumed to be the mature body weight based off from previous data on steers of similar composition (Smith, 2020)

Statistical Analysis

Data were analyzed using analysis of variance appropriate for a randomized complete block design experiment using the GLIMMIX procedures of SAS 9.4 (SAS Inst. Inc. Cary, NC). Vaccination status was included as a fixed effect, and block was considered a random factor; pen served as the experimental unit for all analyses. The MIXED procedure in SAS 9.4 was used to analyze DS and antibody titers. Day was included as a repeated measure, with initial proportions (DS and positive titers) or concentrations (titers) included as covariates. Compound symmetry was included as the covariate structure. A log transformation was used to convert antibody titer concentrations for statistical analysis. Least squares means (LSMEANS) were generated and treatment effects were separated using the least significance differences (PDIFF with LINES option). An α level of 0.05 determined significance and an α level of 0.06 to 0.10 was considered a tendency.

RESULTS AND DISCUSSION

In the present study, calves were either vaccinated upon arrival or did not receive a vaccination for the 42-d study. It has been suggested that delaying vaccination of high-risk calves until 14 to 30 days after feedlot arrival improves health and performance (Richeson et al., 2008; Griffin et al., 2018). Previous research has also indicated that having appropriate preconditioning strategies plays a key role in decreasing morbidity rates associated with BRD (Step et al., 2009) and may influence timing of subsequent vaccination. Proper vaccination protocols should be recommended based on what is ideal for the producer, location, specific phase of production, and management practices (Callan, 2001). Since the calves in the present study were not immunologically naïve and were relatively unstressed, vaccination was delayed the entire 42 d period, which would represent a common receiving period for recently weaned calves before they may be transitioned to a finishing yard.

Depression Scores

No steers in the present study had DS higher than a score of 1 (Figure 1). There were no treatment by day interactions ($P > 0.05$) for DS over the first 21 d. However, there was a day effect ($P < 0.01$), where steers from both treatments had a greater proportion of DS of 1 on d 7 compared to the rest of the first 21 d. This is similar to a study by Step et al., (2009) where newly-weaned calves received vaccination upon arrival with or without revaccination eleven days later where the highest morbidity rates were observed at 7.62 d and 7.21 d for single vaccinated and revaccinated calves, respectively. This presents a potential timeframe of observation of BRD symptoms in newly received cattle. As the calves in the present study were transported directly from the ranch to the receiving yard without traveling through an auction facility, and were not commingled with calves from outside sources, it is likely that these calves experienced less stress compared to the general population of calves entering grow yards (Step et al., 2008; White et al., 2008; Scott et al., 2022). This history could further explain the lack of differences in DS, as well as the lack of heightened DS (>1) observed. Calves reported to have DS greater than 1 are considered high-risk calves that have traveled through auction facilities and been commingled with calves from different sources (Step et al., 2009). All calves in the present study were also consuming long stem grass hay out of the concrete bunks on d 0 and were offered a receiving ration on d 1. This is important to consider as the consumption of feed allows rumen microbes to remain active and avoid risk of acidosis (NASEM, 2016), which may aid in the prevention of heightened depression scores.

Antibody Titers

There were no treatment by day interactions ($P < 0.05$) for the proportions of positive titers or for antibody titer concentrations for any of the antibodies analyzed. There were no day effects ($P > 0.05$) for IBR, BRSV, BVD I or II. There was a treatment effect for the proportion of steers with positive titers for IBR (Figure 2), PI_3 (Figure 3), and BRSV (Figure 4). VAC steers had a greater ($P = 0.04$) proportion of steers with positive IBR titers compared to NOVAC steers (59.42% vs 37.25%). It is important to note that the proportion of NOVAC steers with positive titers remained constant (37.25%) throughout the study. Limited information is available to compare IBR titers with previous research. All VAC steers had positive ($P = 0.04$) PI_3 titers throughout the study compared to only 80% of NOVAC steers with positive titers. This agrees with Schumaher et al., (2019) where steers with early additional vaccination had increased PI_3 titers. VAC steers also had a higher proportion ($P = 0.04$) of steers with positive titers for BRSV compared to NOVAC steers (98.96% vs 81.04%).

There was a treatment effect for log titer concentrations for IBR (Figure 5), BRSV (Figure 6), and PI_3 (Figure 7), VAC steers had increased ($P = 0.03$) IBR titer concentrations compared to NOVAC steer concentrations (1.14 vs 0.95). VAC steers had increased ($P = 0.01$) BRSV titer concentrations compared to the titer concentrations of NOVAC (1.72 vs 1.11). VAC steers also had increased ($P = 0.01$) antibody titer concentrations compared to

VAC steers (1.93 vs 1.18). There was also a day effect for PI_3 titer concentrations where titer concentrations were increased ($P = 0.03$) on d 21 compared to d 42 (1.72 vs 1.38, respectively), but both were similar to d 1 which was intermediate (1.44).

No treatment by day interactions or main effects ($P > 0.05$) observed for BVD I and II concentrations. This disagrees with a 56-d trial by Richeson et al., (2008) where there was a treatment by day interaction for BVD I and II titer concentrations between calves that received a respiratory and clostridial vaccine alone or in combination upon feedlot arrival. In the same trial, BVD I titer concentrations were also increased with respiratory vaccine administration upon arrival, which contradicts the present study where delaying vaccination increased ($P < 0.05$) BVD I titer concentrations (figure 6). Treatment by day interactions were also noted for BVD titers (Lippolis et al., 2016) and BVD I, BRSV, PI_3 and bovine herpesvirus (Schumaher et al., 2019) where titer concentrations were greater in calves vaccinated prior to weaning and prior to feedlot entry. No treatment main effects were observed ($P > 0.05$) for titer concentrations or the proportion of positive samples for BVD II (figure 7). VAC steers had increased ($P < 0.05$) PI_3 titer concentrations (figure 8). It has been observed that steers receiving vaccinations prior to feedlot arrival and prior to a second booster vaccination had increased antibody titers compared to those that had delayed vaccine administration for BVD I and II (Lippolis et al., 2016) and BVD I, BRSV, PI_3, and bovine herpesvirus (Schumaher et al., 2019). As all calves were vaccinated prior to their arrival at the feedlot, this may help explain the lack of differences between treatments, as well as all calves were observed to have adequate antibody titers throughout the duration of the study.

Growth Performance Calculations

Growth performance responses for the 42-d period were not influenced ($P \geq 0.10$) by treatment (table 2). This was similar to a 56-d study by Richeson et al., (2008) where no differences were observed in ADG between steers that received a respiratory and clostridial vaccine alone or in combination. This was also similar to a trial by Schumaher et al., (2019) where no differences for BW and ADG were detected in calves vaccinated for respiratory diseases 15 d prior to weaning, at weaning, or 15 d after weaning. However, Arthington et al., (2013) and Rodrigues et al., (2015) reported reduced ADG, feed efficiency, and DMI when calves were vaccinated for respiratory diseases or not vaccinated upon arrival and vaccinated for respiratory diseases or administered saline solution 20 d after weaning, respectively

. In the present study, DMI as a percentage of BW tended ($P < 0.07$) to increase by 3.5% for NOVAC compared to VAC from d 21 to 42. Cumulative dry matter intake as a percentage of BW also tended ($P < 0.07$) to increase by 3.3% for NOVAC compared to VAC. This indicates that VAC calves tended to eat more the first 21 d on feed, but the NOVAC calves tended to eat more after approximately 21 d on feed. NOVAC calves also numerically ate more compared to VAC calves.

Conflicting differences in performance based on vaccination timing in previous research have been suggested to be attributed to variations in management history (Richeson et al., 2008). The lack of differences between treatment groups in the present study helps to confirm this theory that knowing vaccination history prior to feedlot arrival in newly-weaned calves helps reduce variance in performance independent of vaccination administration in the next phase of production. The administration of vaccines to calves while they are still with their dams allows adequate time for calves to develop immunologic protection prior to encountering potential threats of BRD and other pathogens when being transitioned to a backgrounding facility (Richeson et al., 2019). Therefore, knowing prior vaccination management may be indicative of performance responses in calves coming into a backgrounding facility.

IMPLICATIONS

Collectively, growth performance was unaffected by vaccination timing. As would be expected, vaccinated calves had increased overall antibody titer responses. Secondary vaccination provided additional antibody titers in circulation that could be available during times where calves could be immunocompromised. However, in the present study calves were relatively unstressed. Calves were also not naïve to pathogens as they all had received prior vaccination at the ranch. Thus, knowing the prior history of calves at receiving is important for determining vaccine protocols. The present study does appear to indicate that proper vaccination management and administration in the cow-calf sector did not hinder calf performance in the feedlot, regardless of vaccination administration timing at feedlot entry. However, producers need to consider what method is most applicable to their operation. This information may aid producers in vaccine management in receiving calves following the weaning event.

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Table 2.6 Diet formulation for a 42 d study for previously vaccinated, newly-weaned steers vaccinated for Infectious Bovine Rhinotracheitis, Bovine Virus Diarrhea Type I and II, Parainfluenza-3, and Bovine Respiratory Syncytial Virus and clostridial species upon arrival (VAC) or not vaccinated upon arrival (NOVAC).

Item	d 1 to 42
Wheatlage, %	39.43
Liquid Supplement[1], %	5.16
Oat Hay, %	10.10
Dried Distillers Grains Solubles, %	9.39
Soybean Hulls, %	35.93
Dry Matter, %	51.11
Crude Protein, %	12.92
Neutral Detergent Fiber, %	56.49
Acid Detergent Fiber, %	38.64
Ash, %	6.99
Ether Extract, %	2.62
Net Energy of Maintenance, Mcal/ kg	1.72
Net Energy of Gain, Mcal/ kg	1.04

[1] Liquid supplement (all values except dry matter on a dry matter basis): 36.27% crude protein, 28% nonprotein nitrogen, 0.74 Mcal/kg of net energy for maintenance, 0.50 Mcal/kg of net energy for gain, 1.62% crude fat, 1.06% crude fiber, 4.62% calcium, 0.43% P, 2.28% K, 0.47% Mg, 5% NaCl, 3.38% Na, 0.54% S, 4 ppm Co, 200 ppm Cu, 20 ppm I, 25.15mg/kg. of ethylenediamine dihydroiodide 150.29 ppm Fe, 400 ppm Mn, 3.08 ppm Se, 700 ppm Zn, 44,092 IU/kg of vitamin A, 440.92 IU/kg of vitamin E, and 551 g/ Mg of monensin sodium (Rumensin, Elanco, Indianapolis, IN, USA)

Table 7.2. Growth performance responses for a 42 d study in previously vaccinated, newly-weaned steers vaccinated for Infectious Bovine Rhinotracheitis, Bovine Virus Diarrhea Type I and II, Parainfluenza-3, and Bovine Respiratory Syncytial Virus and clostridial species upon arrival (VAC) or not vaccinated upon arrival (NOVAC).

	Treatment			
Item	VAC	NOVAC	SEM	*P*-Value
Pens, n	5	5	-	-
Steers, n	35	35	-	-
Initial body weight (BW)[1], kg	254	254	1.33	0.59
Initial to d 21				
BW[2], kg	276	274	2.09	0.34
Average daily gain (ADG), kg/d	1.01	0.94	0.072	0.38
Dry matter intake (DMI), kg/d	4.71	4.84	0.088	0.23
DMI % BW[3]	1.78	1.84	0.031	0.13
Gain: Feed (G:F)[4]	0.214	0.196	0.0161	0.32
d 21 to 42				
BW[2], kg	293	292	2.86	0.60
ADG, kg/d	0.83	0.86	0.064	0.67
DMI, kg/d	6.35	6.52	0.119	0.22
DMI % BW[3]	2.24	2.32	0.034	0.07
G:F[4]	0.133	0.135	0.0081	0.90
Initial to d 42				
ADG, kg	0.92	0.90	0.055	0.72
DMI, kg	5.53	5.68	0.092	0.18
DMI % BW[3]	2.02	2.09	0.028	0.07
G:F[4]	0.168	0.161	0.0082	0.44
Observed net energy of maintenance Mcal/ kg	1.90	1.83	0.041	0.19
Observed net energy of gain Mcal/ kg	1.26	1.20	0.036	0.19
Observed: Expected DMI	0.90	0.94	0.025	0.19
Observed: Expected ADG	1.23	1.14	0.055	0.18

[1] Average of BW collected on d 0 and d -1. No shrink was applied to this BW.

[2] BW was shrunk 4% to account for digestive tract fill.

[3] Calculated as DMI divided by BW

[4] Calculated as ADG divided by DMI

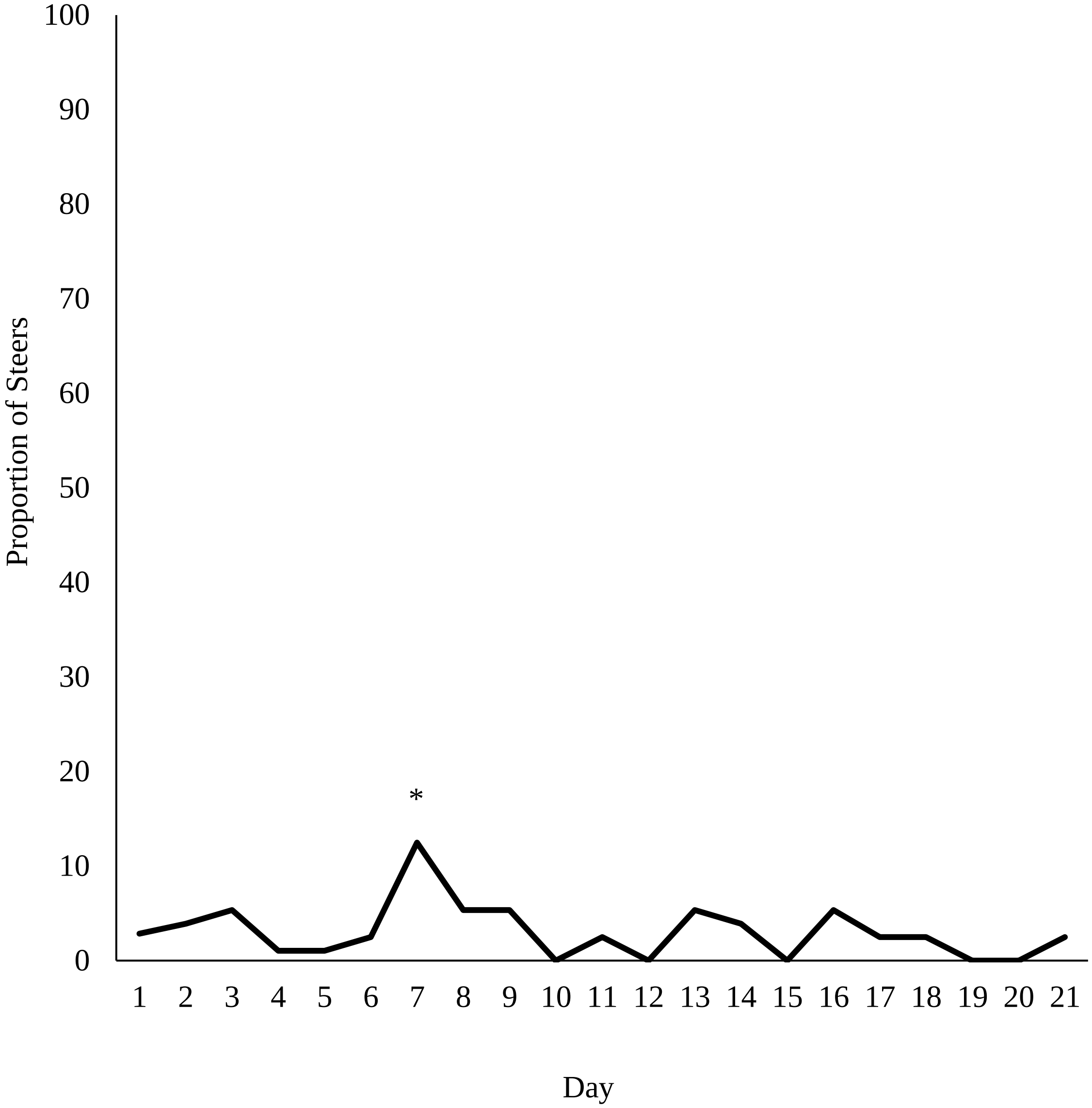

Figure 2.3. The proportion of steers categorized as a Depression Score of 1 for the first 21 d in a 42-d study in previously vaccinated, newly-weaned steers vaccinated for Infectious Bovine Rhinotracheitis, Bovine Virus Diarrhea Type I and II, Parainfluenza-3, and Bovine Respiratory Syncytial Virus and clostridial species upon arrival (VAC) or not vaccinated upon arrival (NOVAC). Day ($P < 0.01$). *Indicates day is significant.

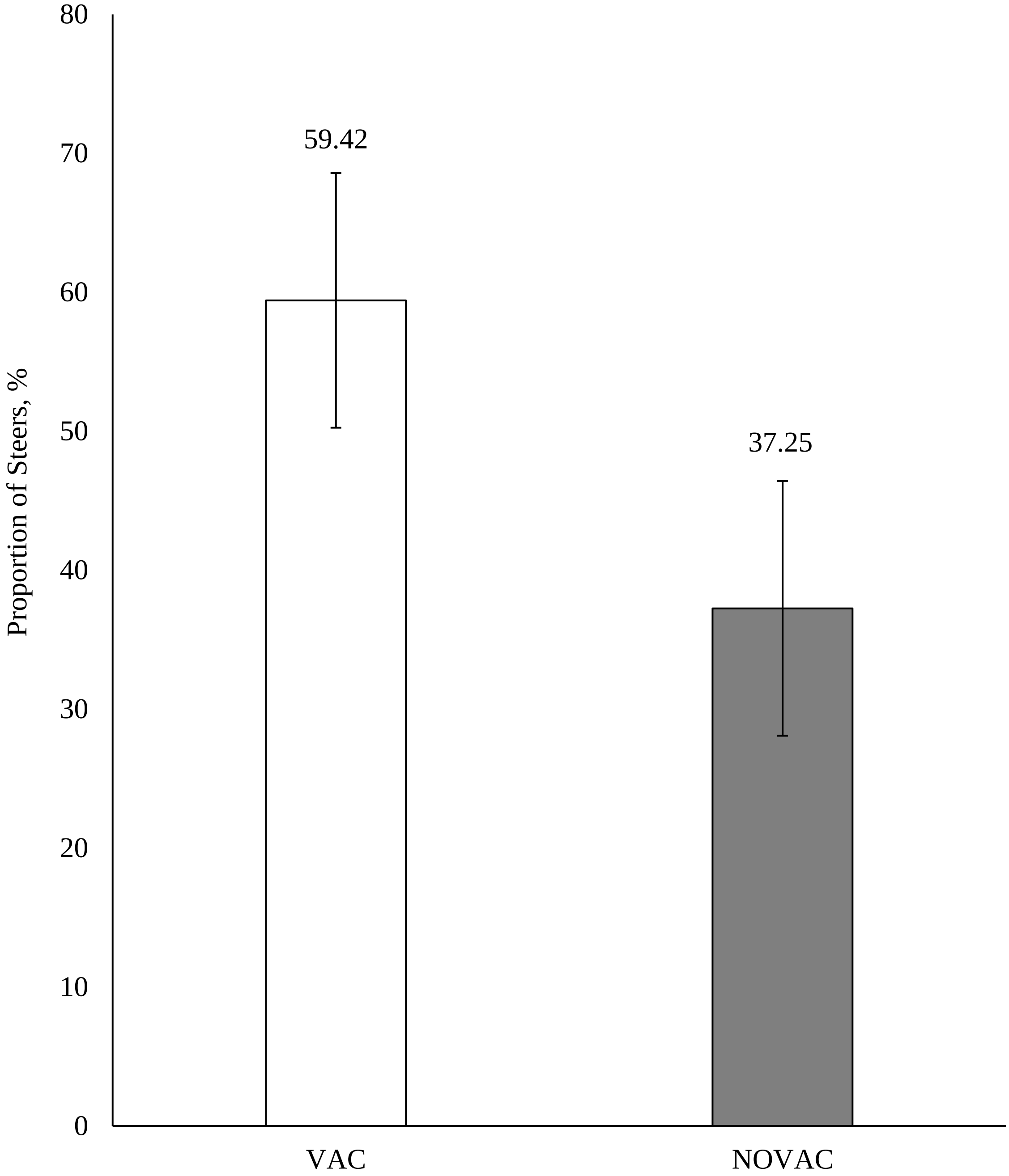

Figure 2.2. The proportion of positive sera samples for Infectious Bovine Rhinotracheitis in a 42-d study in previously vaccinated, newly-weaned steers vaccinated for Infectious Bovine Rhinotracheitis, Bovine Virus Diarrhea Type I and II, Parainfluenza-3, and Bovine Respiratory Syncytial Virus and clostridial species upon arrival (VAC) or not vaccinated upon arrival (NOVAC). Treatment (P = 0.04).

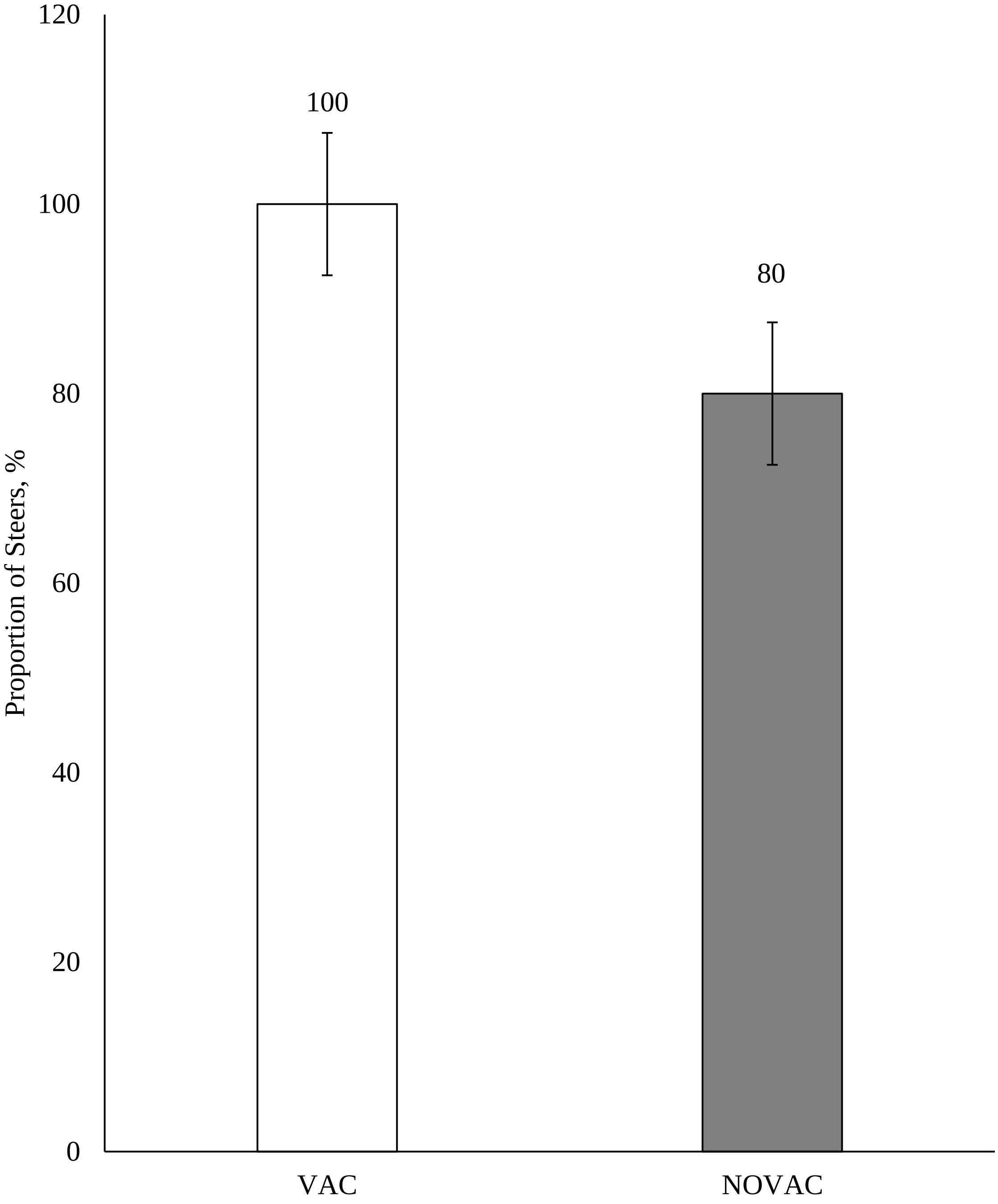

Figure 4.3. The proportion of positive sera samples for Parainfluenza-3 in a 42-d study in previously vaccinated, newly-weaned steers vaccinated for Infectious Bovine Rhinotracheitis, Bovine Virus Diarrhea Type I and II, Parainfluenza-3, and Bovine Respiratory Syncytial Virus and clostridial species upon arrival (VAC) or not vaccinated upon arrival (NOVAC). Treatment ($P = 0.04$).

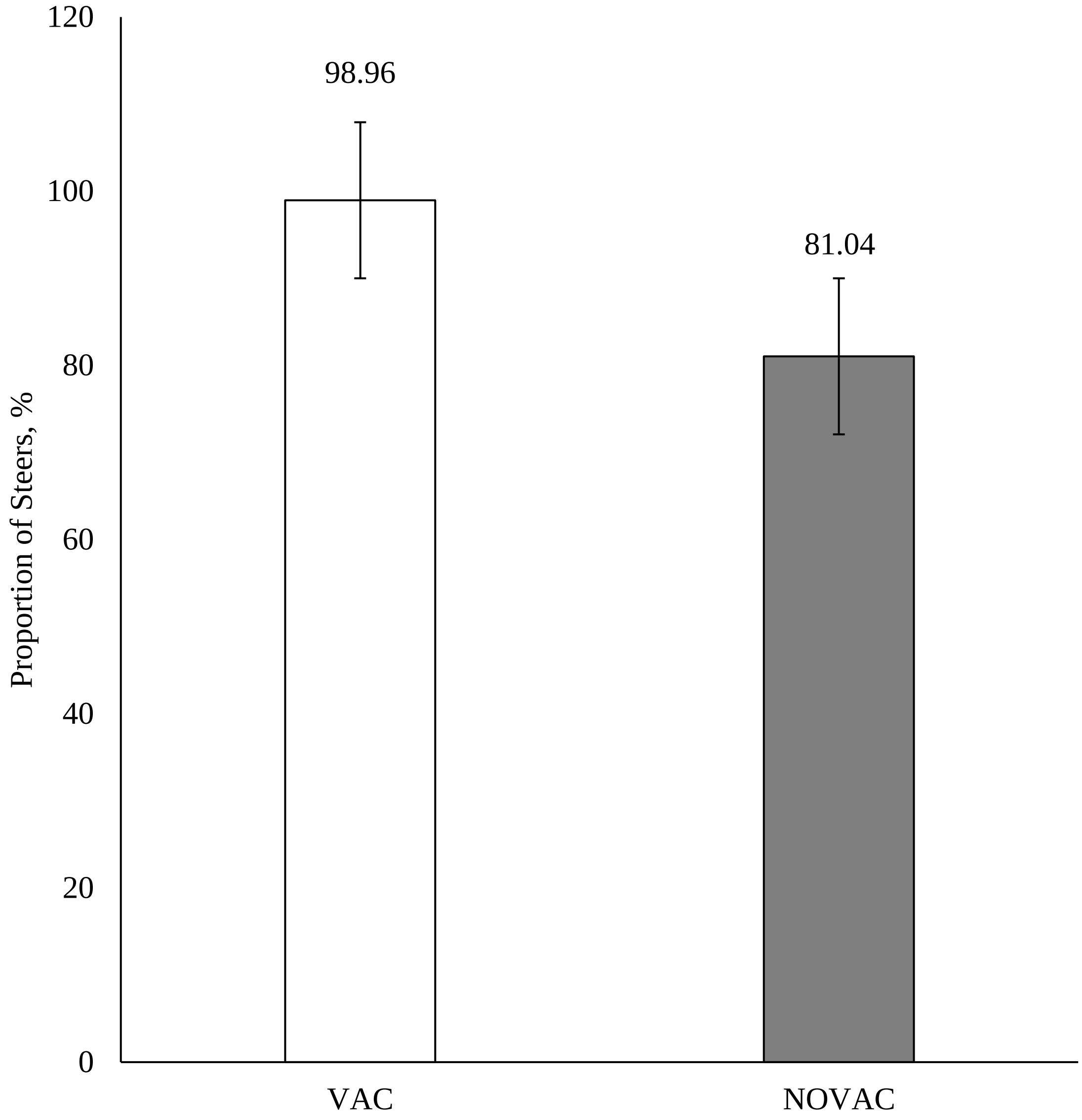

Figure 2.4. The proportion of positive sera samples for Bovine Respiratory Syncytial Virus in a 42-d study in previously vaccinated, newly-weaned steers vaccinated for Infectious Bovine Rhinotracheitis, Bovine Virus Diarrhea Type I and II, Parainfluenza-3, and Bovine Respiratory Syncytial Virus and clostridial species upon arrival (VAC) or not vaccinated upon arrival (NOVAC). Treatment (P = 0.04).

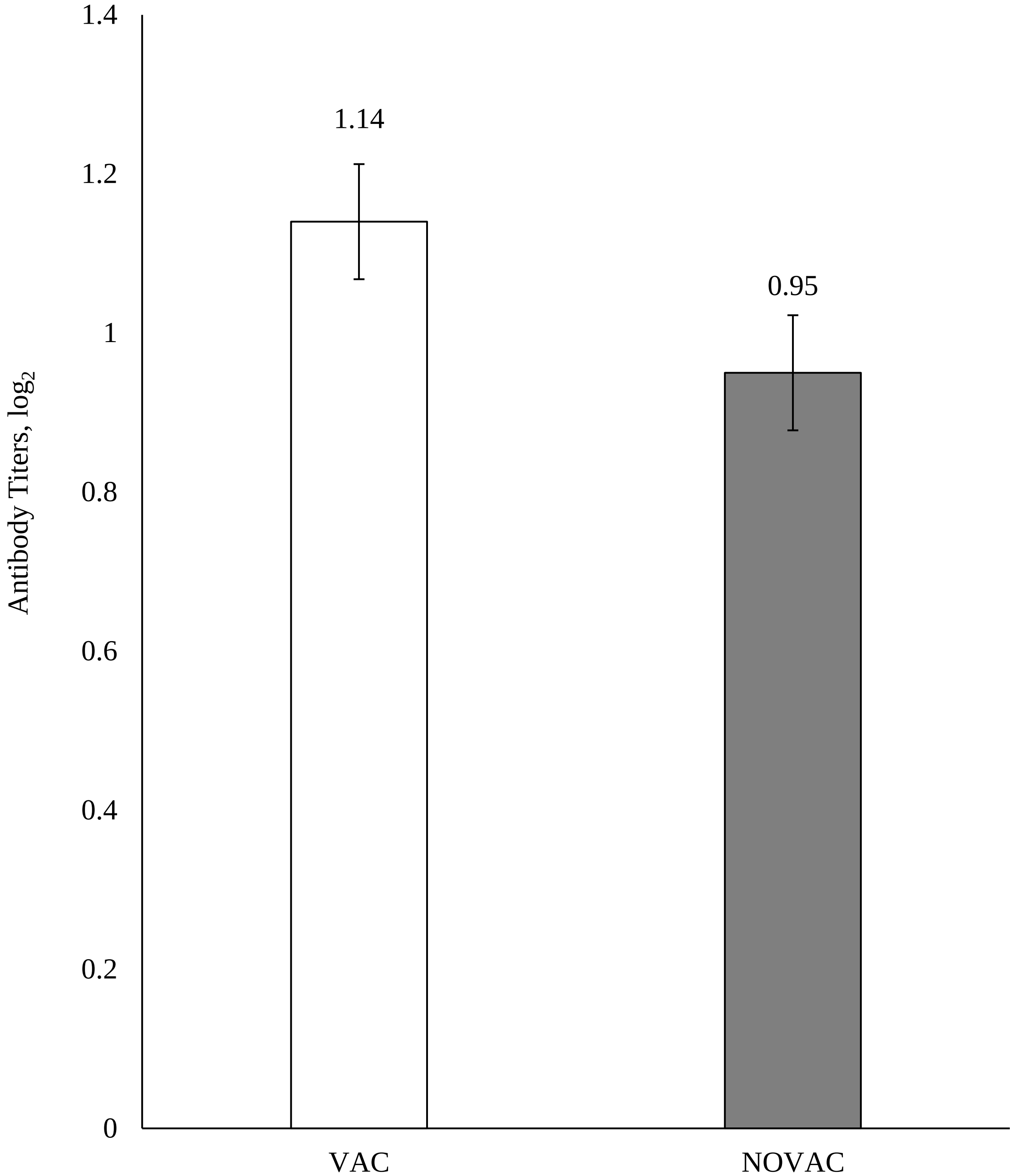

Figure 2.5. The titer concentrations in sera samples for Infectious Bovine Rhinotracheitis in a 42-d study in previously vaccinated, newly-weaned steers vaccinated for Infectious Bovine Rhinotracheitis, Bovine Virus Diarrhea Type I and II, Parainfluenza-3, and Bovine Respiratory Syncytial Virus and clostridial species upon arrival (VAC) or not vaccinated upon arrival (NOVAC). Treatment ($P = 0.03$).

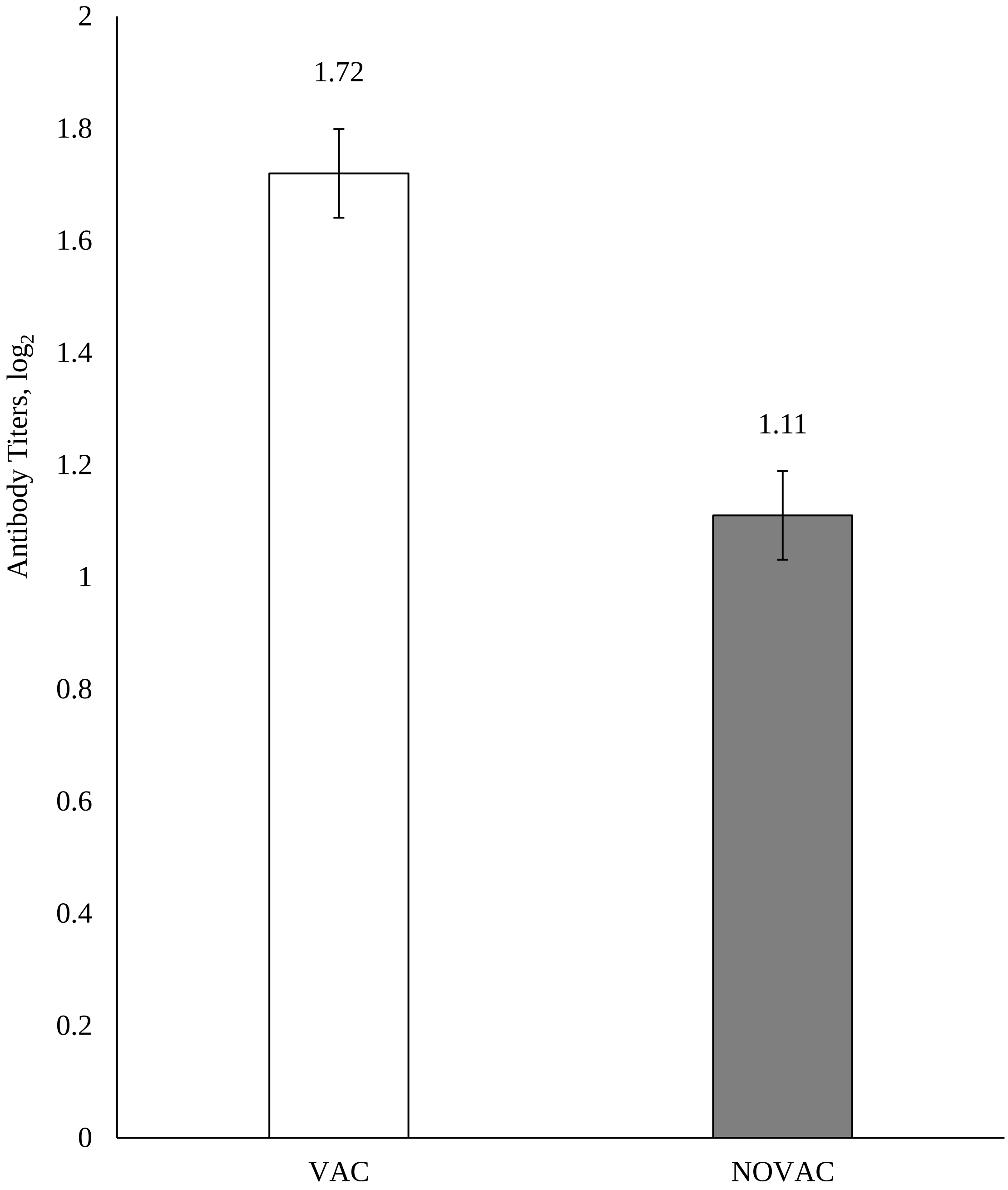

Figure 2.6. The titer concentrations in sera samples for Bovine Respiratory Syncytial Virus in a 42-d study in previously vaccinated, newly-weaned steers vaccinated for Infectious Bovine Rhinotracheitis, Bovine Virus Diarrhea Type I and II, Parainfluenza-3, and Bovine Respiratory Syncytial Virus and clostridial species upon arrival (VAC) or not vaccinated upon arrival (NOVAC). Treatment (P = 0.01).

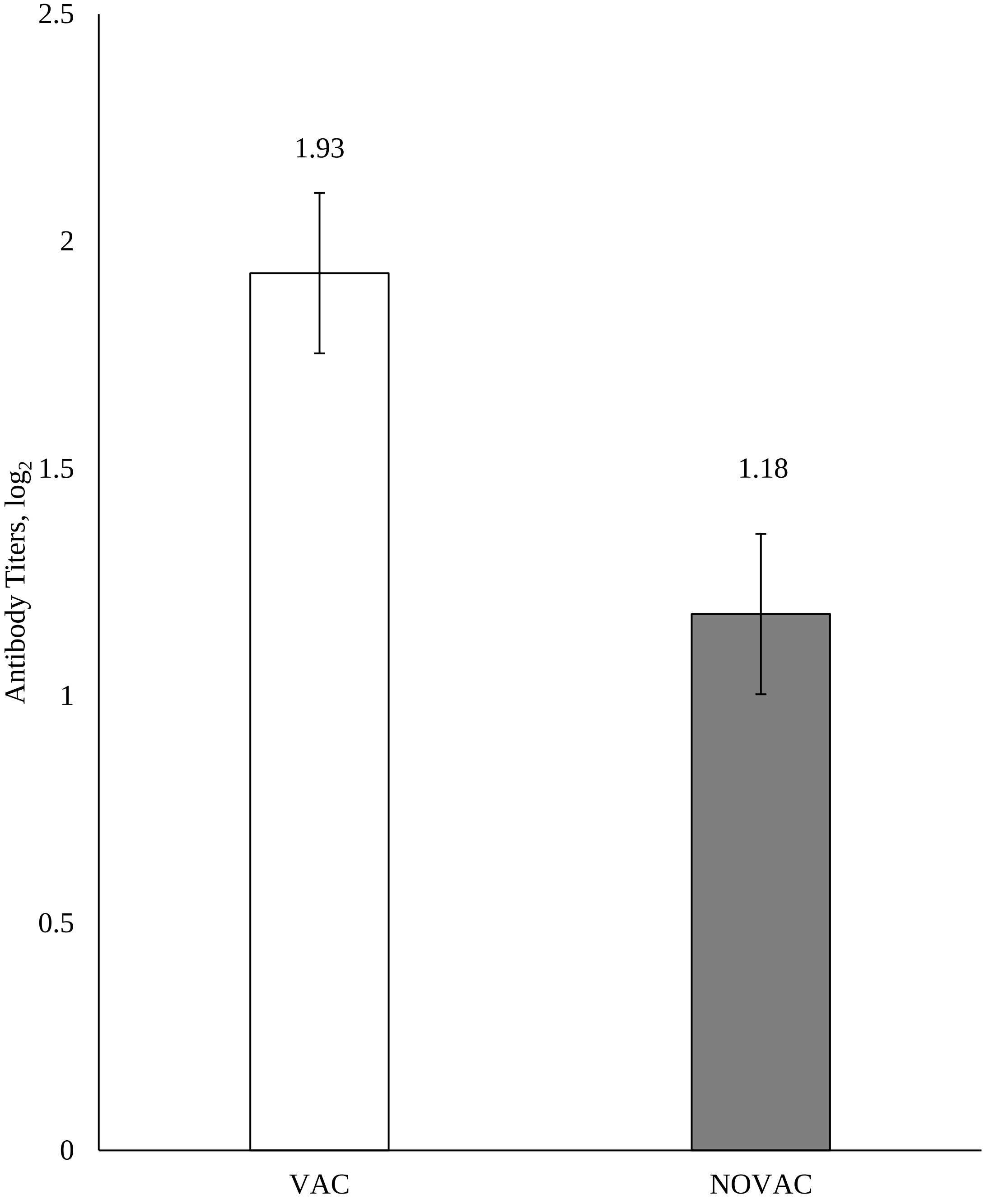

Figure 2.7. The titer concentrations in sera samples for Parainfluenza-3 in a 42-d study in previously vaccinated, newly-weaned steers vaccinated for Infectious Bovine Rhinotracheitis, Bovine Virus Diarrhea Type I and II, Parainfluenza-3, and Bovine Respiratory Syncytial Virus and clostridial species upon arrival (VAC) or not vaccinated upon arrival (NOVAC). Treatment (P = 0.01).

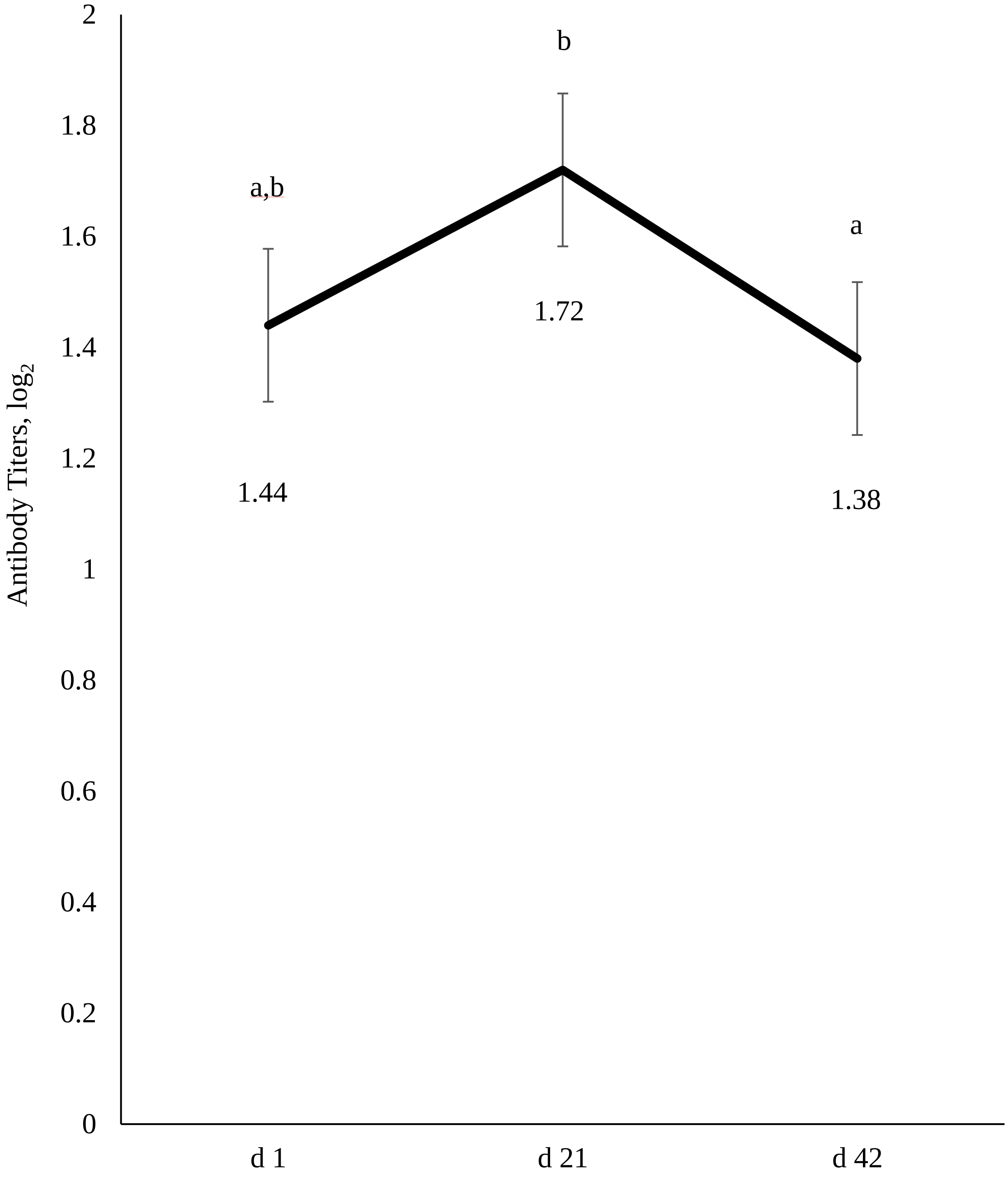

Figure 2.8. The titer concentrations in sera samples for Parainfluenza-3 in a 42-d study in previously vaccinated, newly-weaned steers vaccinated for Infectious Bovine Rhinotracheitis, Bovine Virus Diarrhea Type I and II, Parainfluenza-3, and Bovine Respiratory Syncytial Virus and clostridial species upon arrival (VAC) or not vaccinated upon arrival (NOVAC). Day (P = 0.03).

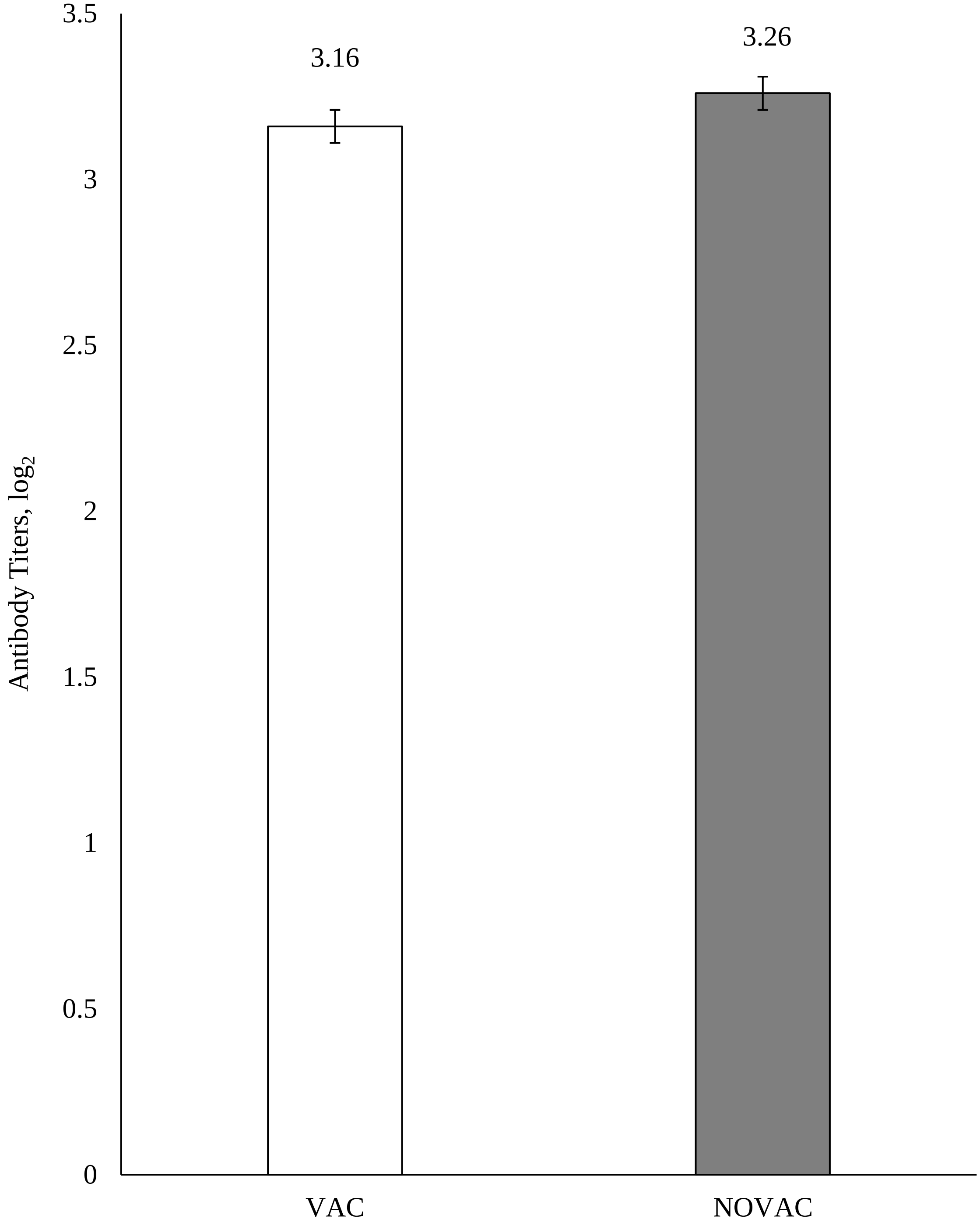

Figure 2.9. The titer concentrations in sera samples for Bovine Virus Diarrhea Type I in a 42-d study in previously vaccinated, newly-weaned steers vaccinated for Infectious Bovine Rhinotracheitis, Bovine Virus Diarrhea Type I and II, Parainfluenza-3, and Bovine Respiratory Syncytial Virus and clostridial species upon arrival (VAC) or not vaccinated upon arrival (NOVAC). Treatment (P = 0.44).

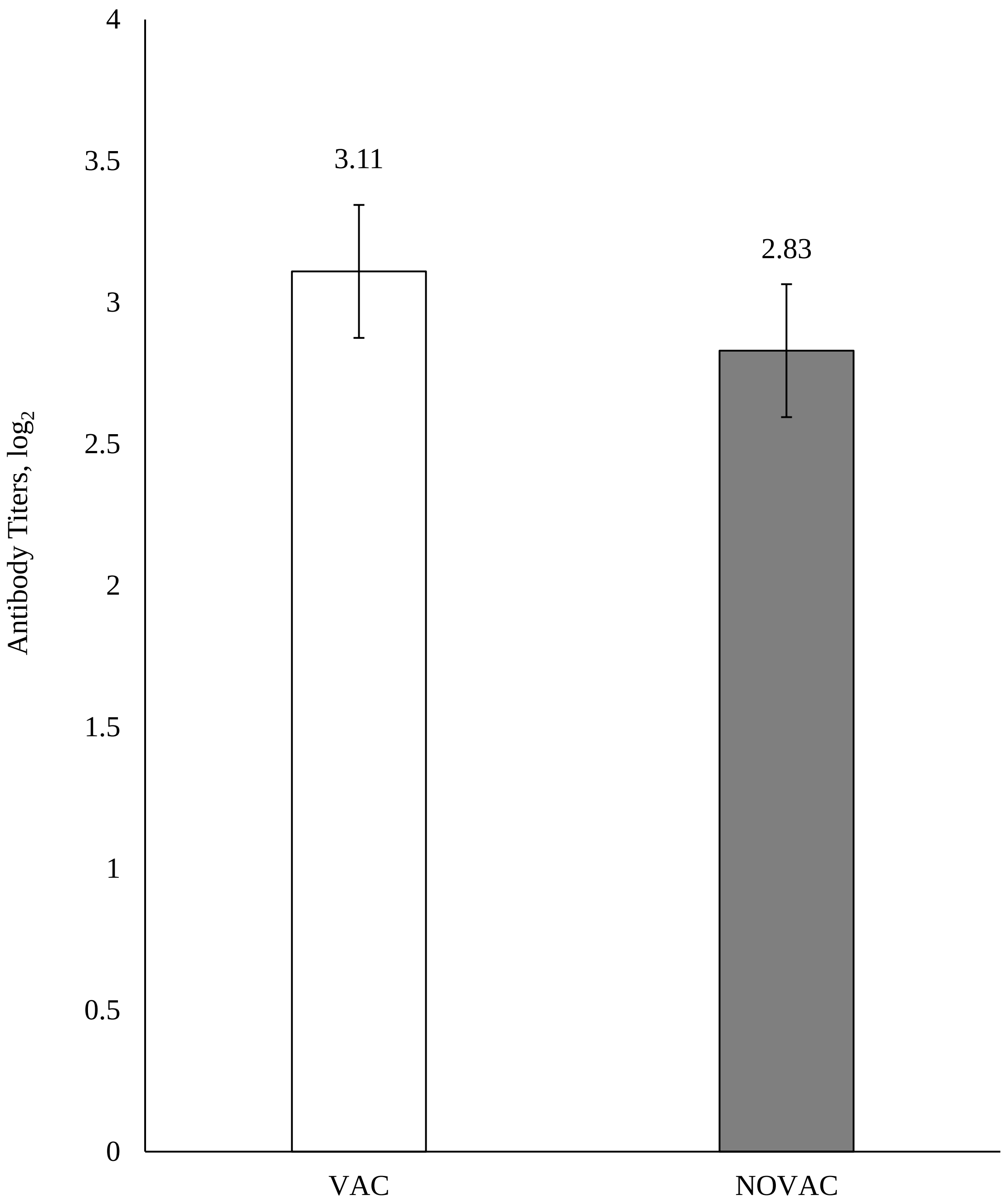

Figure 2.10. The titer concentrations in sera samples for Bovine Virus Diarrhea Type II in a 42-d study in previously vaccinated, newly-weaned steers vaccinated for Infectious Bovine Rhinotracheitis, Bovine Virus Diarrhea Type I and II, Parainfluenza-3, and Bovine Respiratory Syncytial Virus and clostridial species upon arrival (VAC) or not vaccinated upon arrival (NOVAC). Treatment (*P* = 0.27).

CHAPTER III: Manger space restriction does not negatively impact growth efficiency of feedlot heifers program fed a concentrate-based diet to gain 1.36 kg daily

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ABSTRACT

The objective of this research was to determine the influence manger space restriction had on program-fed feedlot heifers during the growing phase. Charolais × Angus heifers [initial body weight (BW) = 329 ± 22.1 kg] were used in a 109-d backgrounding study. Heifers were received approximately 60 d prior to study initiation. Initial processing (53 d before study initiation) included individual BW, application of an identification tag, vaccination against viral respiratory pathogens and clostridial species, and administration of doramectin pour-on for control of internal and external parasites. All heifers were administered 36 mg of zeranol at study initiation and were assigned to 1 of 10 pens (n = 5 pens/treatment with 10 heifers/pen) in a randomized complete block design (blocked by location). Each pen was randomly assigned to 1 of 2 treatments: 20.3 cm (8IN) or 40.6 cm (16IN) of linear bunk space/heifer. Heifers were individually weighed on d 1, 14, 35, 63, 84 and 109. Heifers were programmed to gain 1.36 kg daily based on predictive equations set forth by the California Net Energy System. To calculate predictive values, a final BW of 575 kg was assumed to be the mature BW of the heifers and tabular net energy values of 2.05 NEm and 1.36 NEg from d 1 to 22, 2.00 NEm and 1.35 NEg from d 23 to 82, and 1.97 NEm and 1.32 NEg from d 83 to 109 were used. Data were analyzed using the GLIMMIX procedure of SAS 9.4 with manger space allocation as the fixed effect and block as the random effect. No differences ($P > 0.35$) were observed between 8IN or 16IN

heifers for initial BW, final BW, average daily gain, dry matter intake, feed efficiency, variation in daily weight gain within each pen or applied energetic measures. No differences ($P > 0.50$) were observed between treatments for morbidity. Although not statistically analyzed, 8IN heifers appeared to have looser stools during the first two weeks compared to the 16IN heifers. These data suggest restricting manger space allocation from 40.6 cm to 20.3 cm did not negatively influence gain efficiency or the efficiency of dietary net energy utilization in heifers programmed fed a concentrate-based diet to gain 1.36 kg daily. The use of tabular net energy values and required net energy of maintenance and retained energy equations are an effective means to program cattle to a desired rate of daily gain during the growing phase.

INTRODUCTION

A main goal of a backgrounding program is to suppress fat or lipid deposition and promote the growth of bones and lean tissue through achieving less-than-maximal growth (Block et al., 2001). This is done in efforts to prolong the growth curve of smaller-framed cattle to reach a more desirable mature weight when cattle are harvested at the end of the finishing period (Owens et al., 1993). Feed intake is known to be a direct correlation of beef cattle growth. Therefore, the management of feed intake plays an important role in prolonging the growth curve in cattle, particularly those in the background phase of production (Galyean et al., 1999).

Controlling or managing feed intake relative to the *ad libitum* amount is not a new concept to the cattle feeding industry (Galyean et al., 1999). Feed intake can be managed via restricted feeding or programmed feeding (Galyean et al., 1999). Limited or restricted feeding during the backgrounding phase would include management where feed intake is restricted relative to the actual or predicted *ad libitum* intake of a pen of cattle (Galyean et al., 1999). The restriction of dry matter intake (DMI) has led to improvements in feed efficiency (Hicks et al., 1990; Loerch and Fluharty, 1998) and ultimately resulted in reduced fat content of carcasses. Restricting the energy content of the diet via increased roughage inclusion or by limiting the amount of a high-concentrate diet that is fed has also been suggested to manage growth rate during the backgrounding phase (Blom et al., 2022).

Program-fed cattle have shown to be more feed efficient and have decreased the total feed required per animal, thus resulting in feed costs saving compared to *ad libitum* fed cattle (Loerch and Fluharty, 1998). Program feeding refers to the use of net energy equations to calculate the quantity of feed required for maintenance at a desired rate of gain (Galyean et al., 1999). The use of net energy equations from the California Net Energy System (CNES) has been proven to be an effective means of predicting expected growth measures in feedlot cattle (Zinn, 1989; Gunter et al., 1996; Loerch and Fluharty, 1998; Galyean et al., 1999). In general, the premise of using the equations set forth by the CNES determines the amount of daily intake by calculating the amount of feed required for daily maintenance plus the feed required for daily gain. These have shown to be the most effective when tabular dietary net energy values for maintenance and gain and expected final body weight are known (Zinn, 1989). A few studies have evaluated the use net energy equations to predict expected growth values in program fed cattle with limited manger space. Zinn (1989) was able to program feed intake to allow for a desired rate of gain with limited bunk space. Gunter et al., (1996) was also able to achieve a desired gain during the growing period with a restricted amount of bunk space. No negative performance influences were attributed to program fed cattle with limited bunk space in either of these studies.

Cattle performance, welfare, and health are dependent upon bunk space and can be negatively impacted in cattle experiencing restriction (Harrison and Oltjen, 2021). This poses a concern for cattle that are not allowed the recommended amount of linear bunk space. It is recommended when cattle of 360 to 545 kg are fed twice daily, that 27.9 to 33.0 cm of linear bunk space is provided (FASS, 2020). Bunk space allotments of 24.3 to 63.5 cm of linear bunk space per animal were recommended when DMI was restricted (Duncan et al., 2022). Allotments of 15 to 45 cm bunk space per animal did not negatively influence growth performance measures in steers that were limit-fed during the receiving phase (Zinn, 1989). We hypothesized that restricting manger space and program fed heifers would not negatively alter feedlot performance. The objective of this study was to determine the influence of manger space restriction on feedlot heifers program fed to gain 1.36 kg daily during the growing phase on growth performance and health measures.

MATERIALS AND METHODS

Institutional Animal Care and Use Approval

This study was conducted at the Ruminant Nutrition Center (RNC) in Brookings, SD between March and July of 2022. The animal care and handling procedures used in this study were approved by the South Dakota State University Animal Care and Use Committee (2202-006E).

Heifer Management and Treatments

Charolais × Angus crossbred heifers (initial BW = 329 ± 22.1 kg) were used in a 109-d study. Heifers were procured from a local South Dakota ranch and received approximately 60 d prior to study initiation. Initial processing was conducted 53 d before the initiation of the present experiment and included individual BW measurement (scale readability 0.454 kg), application of a unique identification and electronic ear tag, vaccination against viral respiratory pathogens (Bovi-Shield Gold 5, Zoetis, Parsippany, NJ) and clostridial species (Ultrabac/Somubac 7, Zoetis) all heifers were administered pour-on dormectin (Dectomax, Zoetis) for control of internal and external parasites. All heifers were administered 36 mg of zeranol (Ralgro, Merck Animal Health, Madison, NJ) at study initiation.

Heifers were assigned to 1 of 10 pens (7.62 m × 7.62 m concrete surface pens with 7.62 m of concrete bunk; 5 pens/treatment; 10 heifers per pen) in a randomized complete block design (blocked by location) and pen was randomly assigned to 1 of 2 treatments: 20.3 linear cm of bunk space per heifer (8IN) or 40.6 linear cm of bunk space per heifer (16IN). It is important to note that pen space and animal space were not confounded based off from the amount of bunk space available. In order to achieve the desired manger space allocation, red marks were painted on the concrete bunk to identify the targeted feed delivery area. A total of 203 cm for the 8IN treatment and 406 cm for the 16IN treatment was required for the targeted delivery area out of the 762 cm of bunk space available. Additionally, electric waterers (Bohlmann Quality Products; Denison, IA) were split between adjacent pens and were 78.74 cm × 55.88 cm × 60.96 cm in dimension and occupied approximately 0.22 m^2 of pen space.

Dietary Management

Orts were collected, weighed, and dried in a forced air oven at 100°C for 24 h to determine DM content if carryover feed spoiled, or was present on weigh days. If carryover feed was present on weigh days, the residual feed was removed prior to the collection of BW measurements. The dry matter intake (DMI) of each pen was adjusted to reflect the total DM delivered to each pen after subtracting the quantity of dry orts for each interim period. Actual diet formulation and composition was based upon weekly DM analyses (drying at 60°C until no weight change), tabular nutrient values (Preston, 2016), and corresponding feed batching records. Weekly DM determination (method no. 935.29) was used to determine DM content of each ingredient fed each week (AOAC, 2012, 2016).

Fresh feed was manufactured twice daily in a stationary mixer (2.35 m^3; readability 0.454 kg). Diets (Table 1; DM basis) consisted of ingredients common to the northern plains feeding region and changed over time because of evolving ingredient inventory. Liquid supplement was included to provide monensin sodium (Rumensin 90; Elanco, Indianapolis, IN) at 30 g/907-kg (DM basis) and vitamins and trace minerals to meet nutrient requirements for growing and finishing beef cattle (NASEM, 2016). A type B Melengestrol acetate (MGA, Zoetis) product (1 mg/0.45 kg) was manufactured and included at a rate of 0.225 kg/heifer daily in replacement of dry-rolled corn to suppress heifer cyclicity. Diets presented in Table 1 are actual DM diet composition, plus tabular nutrient concentrations and tabular energy values (Preston, 2016).

Growth Performance Calculations

Heifers were individually weighed at study initiation and on d 14, 35, 63, 84 and 109 (final day of experiment). Cumulative daily weight gain was based upon initial shrunk BW (4% shrink) and final shrunk BW (2% shrink). Average daily gain (ADG) was calculated by subtracting the final shrunk BW from the initial shrunk BW and dividing by days on feed. Gain to feed ratio (G:F) was calculated by dividing ADG by DMI.

Dietary NE Utilization Calculations

Observed dietary net energy (NE) was calculated from daily energy gain (EG; Mcal/d) according to the medium frame steer calf equation using mean equivalent BW [median feeding BW × (478/534)]: EG, Mcal/d = $ADG^{1.097} \times 0.0557W^{0.75}$; energy gain was the daily deposited energy and W was the mean equivalent BW (NRC, 1996). Maintenance energy required (EM; Mcal/d) was calculated by the following equation: EM, Mcal/d = $0.077BW^{0.75}$ (Lofgreen and Garrett, 1968; NASEM, 2016) where BW was the average of initial shrunk BW and final shrunk BW (initial BW shrunk 4% and final BW shrunk 2%). Using the estimates required for maintenance and gain, the observed dietary NEm and NEg values of the diet were generated using the quadratic formula: $x = \frac{-b \pm \sqrt{b^2 - 4ac}}{2c}$, where x = NE_m, Mcal/kg, a = -0.41EM, b = 0.877EM + 0.41DMI + EG, c = -0.877DMI, and NE_g was determined from: 0.877 NE_m – 0.41 (Zinn and Shen, 1998; Zinn et al., 2008a). The ratio of observed-to-expected NE ratio was determined from observed dietary NE for maintenance or gain divided by tabular NE for maintenance or gain.

To calculate the daily DMI required, the following equation was used: DMI (kg) = FFM + FFG. Feed for maintenance (FFM; kg) was the EM divided by the tabular NEm value. Feed for gain (FFG; kg) was the RE was divided by the tabular NEg value. The following equation was used to determine retained energy (RE; Mcal) = 0.0557 × $EQSBW^{0.75} \times SWG^{1.097}$. Equivalent shrunk BW (EQSBW; kg) = [(current shrunk BW + target shrunk BW of the next period)/2] × (standard reference weight of 478 kg divided by the mature shrunk BW, which was assumed to be 575 kg based on similar calves from previous research). Shrunk weight gain (SWG) was targeted to be 1.36 kg/d.

To calculate predictive values, a final body weight of 575 kg was assumed to be the mature body weight of the heifers in the study, based off from previous data on steers of similar composition with a mature body weight of 665 kg (Smith, 2020). An adjustment of 90.7 kg was assumed as heifers finish at a lower mature body weight compared to steers of similar composition (Zinn et al., 2008b).

Statistical Analysis

Data were analyzed using analysis of variance appropriate for a randomized complete block design experiment using the GLIMMIX procedures of SAS 9.4 (SAS Inst. Inc. Cary, NC). Manger space allocation was included as a fixed effect, and block was considered a random factor; pen served as the experimental unit for all analyses. Least squares means (LSMEANS) were generated and treatment effects were separated using the least significance differences (PDIFF with LINES option). An α of 0.05 determined significance and an α of 0.06 to 0.10 was considered a tendency.

RESULTS AND DISCUSSION

As previously mentioned, feed intake management is not a new concept to the cattle feeding industry (Galyean et al., 1999). This methodology is most commonly used in mature beef cows to avoid over-feeding and accumulating excessive body condition. However, the CNES has been shown to be an effective means to calculate predictive rate of gain measures in feedlot cattle (NASEM, 2016). Galyean et al., (1999) suggested that the CNES equations are based on using a 4% shrink in the equations. In the present study, a 2% shrink was used to shrink final BW (after 109 d of limit-feeding) to more accurately account for gastrointestinal tract fill, as the heifers were limit-fed. When a 2% shrink was applied, our observed gains were in good agreement with predicted values. When Zinn (1989) used the same equations, observed and predicted gains were in close agreement, 4.1% higher than expected (1.45 kg/d) and 1.6% lower than expected (1.22 kg/d) for two different experiments. When steers were programmed to gain 1.35 or 1.5 kg daily (Hicks et al., 1990), observed daily gains were 13% and 17% lower than calculated, respectively. In the present study, observed daily gains were 4.3% and 2.7% less than targeted expectations for 8IN and 16IN, respectively (Table 2).

There were no differences (*P* > 0.35; Table 2) observed between the 8IN or 16IN heifers for initial BW, final BW, ADG, DMI, G:F, or applied energetic measures, nor was the S.D. of ADG influenced by manger space allowance (*P* = 0.39). Our observations agree with other published results where restricting bunk access had no effect on performance of program-fed cattle (Zinn, 1989: Gunter et al., 1996). g These data suggest that using tabular NE values and required NEm and RE equations are an effective means to program cattle to gain a desired rate of gain per day, independent of bunk space allowance. These results from the present study also confirm that manger space allotments greater than 15 cm of linear bunk space per head do not appreciably enhance feedlot growth performance, as was suggested by Zinn (1989).

Harrison and Oltjen (2021) reported decreased ADG with greater coefficient of variation when bunk restrictions were imposed on steers fed a finishing diet. A potential explanation for greater variation observed in some experiments is increased competition between animals for feed (Longenbach et al., 1999). Behavioral differences were not specifically measured in the current experiment; however, heifers in the 8IN treatment did appear to display greater agonistic behavior while adapting to bunk space limitations. Targeted observations of cattle behavior during adaptation to program feeding could provide valuable insight to better understand the effect of social structure on diet adaptation.

It has been suggested that programmed and restricted feeding can be used as a method to help identify sick cattle (Harrison and Oltjen, 2021). There were no differences in health ($P > 0.05$; data not reported) observed in the present study and no cattle showed signs of morbidity. However, this method to identify sick cattle seemed to be only be effective in smaller scale pens with severe restriction (Galyean et al., 1999). This technique would require further evaluation in higher risk cattle with more severe restriction and in a more practical setting to be confirmed. Although not statistically analyzed, 8IN heifers appeared to have looser stools during the first two weeks of the study compared to the 16IN heifers. At this time, there is no literature that has observed differences in stools based on manger space restriction and/ or limit feeding.

IMPLICATIONS

Restricting manger space allocation from 40.6 cm to 20.3 cm did not negatively influence gain efficiency or the efficiency of dietary net energy utilization in heifers programmed fed a concentrate-based diet to gain 1.36 kg daily. Current estimates for maintenance and retained energy can be applied to heifers if mature BW is known. Additionally, tabular ingredient values from current feeding standards work well under Northern Plains feedlot conditions. Overall, the equations set forth by the CNES prove to be an efficacious method for managing gain and feed intake. This may help to provide a strategic method for managing feed ingredient inventory.

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Table 8.1. Actual dietary formulation and tabular nutrient content for heifers offered a limit fed diet and 20.3 (8IN) or 40.6 (16IN) cm of linear bunk space per heifer through the 109 d feeding experiment[1].

Item	d 1 to 22	d 23 to 82	d 83 to 109
Dry-rolled corn[2], %	20.80	16.42	48.04
High-moisture corn, %	43.23	33.40	-
Dried distillers grains plus solubles, %	14.71	15.28	15.01
Oat hay, %	15.36	-	-
Corn silage, %	-	29.82	32.03
Liquid supplement[3], %	5.89	5.08	4.92
Diet dry matter, %	79.65	57.04	54.68
Crude protein, %	13.31	12.94	12.80
Neutral detergent fiber, %	21.02	24.16	24.91
Acid detergent fiber, %	11.13	13.21	13.69
Ash, %	6.46	6.05	6.03
Organic matter, %	93.54	93.95	93.97
Ether extract, %	3.59	3.59	3.58
Tabular net energy for maintenance, Mcal/kg	2.05	2.00	1.97
Tabular net energy for gain, Mcal/kg	1.36	1.35	1.32

[1] All values except DM on a DM basis.

[2] Melengestrol acetate (MGS, Zoetis) was included at 0.50 mg/heifer daily in a premix that replaced a portion of the dry-rolled corn.

[3] From d 1 to 22 (dry-matter basis): 36.27% crude protein, 28.00% non-protein nitrogen, 0.74 Mcal/lb net energy for maintenance, 0.50 Mcal/lb net energy for gain, 1.62% crude fat, 4.62% Ca, 0.43% P, 2.28% K, 0.47% Mg, 5.00% salt, 3.38% Na, 0.54% S, 4.00 ppm Co, 200.00 ppm Cu, 20 ppm I, 11.41 mg/lb EDDI, 150.29 ppm Fe, 400.00 ppm Mn, 3.08 ppm Se, 700.00 ppm Zn, 20,000.00 IU/lb Vitamin A, 200.00 IU/lb Vitamin E, Monensin 500 g/907-kg. From d 23 to 109 (dry-matter basis): 41.86% crude protein, 38.38% non-protein nitrogen, 0.43 Mcal/lb net energy for maintenance, 0.30 Mcal/lb net energy for gain, 0.91% crude fat, 10.89% Ca, 0.32% P, 7.00% K, 0.22% Mg, 6.03% salt, 3.07% Na, 0.33% S, 4.23 ppm Co, 199.88 ppm Cu, 11.99 ppm I, 6.84 mg/lb EDDI, 83.16 ppm Fe, 304.81 ppm Mn, 2.90 ppm Se, 664.59 ppm Zn, 19,987.55 IU/lb Vitamin A, 199.88 IU/lb Vitamin E, Monensin 579.35 g/907-kg

Table 3.2. Cumulative growth performance responses for heifers offered a limit fed diet and 20.3 (8IN) or 40.6 (16IN) cm of linear bunk space per heifer through the 109 d feeding experiment1.

	Bunk space treatment (centimeters/heifer)			
Item	8IN (20.3 cm)	16IN (40.6 cm)	SEM	*P* - value
Pens, n	5	5	-	-
Heifers, n	50	49	-	-
Cumulative growth				
Initial BW, kg	329	329	0.59	0.77
Final BW, kg	471	474	2.95	0.43
ADG, kg	1.30	1.32	0.027	0.46
DMI, kg	8.04	8.04	0.002	0.35
G:F	0.16	0.17	0.003	0.46
S.D. ADG	0.40	0.36	0.039	0.39
Applied energetics measures[2]				
Observed Net Energy for Maintenance (NEm), Mcal/kg	1.99	2.01	0.027	0.44
Observed Net Energy for Gain (NEg), Mcal/kg	1.34	1.35	0.024	0.44
Observed to expected NEm	1.00	1.01	0.013	0.47
Observed to expected NEg	0.98	0.99	0.016	0.42

[1] A 4% shrink was applied to the initial BW measure to account for digestive tract fill and all subsequent BW measures were pencil shrunk 2% to account for digestive tract fill.

[2] Calculated from observed cumulative growth performance assuming a mature BW of 534 kg and a tabular NEm and NEg of 200 Mcal/kg and 1.34 Mcal/kg of NEm and NEg, respectively.

CHAPTER IV: Evaluation of Post-Transit Growth Performance and Carcass Characteristics of Feedlot Heifers Sourced and Finished in Different Regions of the U.S.

ABSTRACT

The objective was to evaluate growth performance and carcass traits following transit of feedlot heifers sourced and finished in different geographical regions in the U.S. Yearling heifers [n = 190; initial body weight (BW) 483 and 425 kg for SD and TX sourced, respectively] were used in a 2 × 2 factorial arrangement of origin state (SD vs TX) and finishing state (SD vs TX). Heifers were allotted on d -1 into four treatments: sourced from SD and finished in SD (SD-SD), sourced from SD and finished in TX (SD-TX), sourced from TX and finished in SD (TX-SD), and sourced from TX and finished in TX (TX-TX). Heifers were weighed on d -1, 3, 15, 28, 56, 78 (TX-TX and SD-TX) and 90 (SD-SD and TX-SD). On d 0, SD-TX and TX-SD heifers were shipped to the finishing location and weighed the following morning (d 1) to determine transportation shrink. To monitor transportation stress effects, vaginal temperature probes were inserted into all SD-TX and TX-SD heifers and a portion of SD-SD and TX-TX heifers on d -1 and removed on d 3. Clinical attitude scores (CAS) were recorded on d -1, 0, 1, 2 and 3 for indications of bovine respiratory disease symptoms. Transported heifers had reduced temperatures ($P < 0.05$) during transit and post-transit compared to non-transported heifers. Temperatures of transported heifers increased ($P < 0.05$) during loading and unloading. On d 0, 1 and 3 there was a shift in the distribution of heifers that had a CAS score greater than 0 for TX-TX, SD-TX and TX-SD. Cattle endured high ambient temperatures (temperature humidity index value > 75) 54% and 18% of the feeding period for TX and SD finished heifers, respectively. All cumulative growth performance measures and carcass trait interactions were statistically significant ($P < 0.05$) except for initial BW, percent shrink of transported heifers, average daily gain, dressing percent, ribeye area and liver abscess severity, which were similar ($P > 0.30$). There was a shift in the distribution ($P < 0.05$) towards a greater proportion of Yield Grade 1 and Select carcasses for heifers fed in TX compared to those fed in SD. Overall, heifers transported to higher ambient temperatures had improved overall yields and yield grades, but reduced dry matter intake, quality grades (QG) and limited growth recovery (45 kg lighter) compared to non-transported heifers. Heifers transported to lower ambient temperatures recovered growth and had improved QG at the same level of rib fat compared to non-transported heifers but had reduced overall yields and yield grades.

INTRODUCTION

Beef cattle are procured from all regions of the United States and most are finished in a feedlot for harvest. Texas is the largest producer of the calf crop in the United States, while South Dakota ranks 5th for production of the calf crop (Wisevoter, 2023). A majority of the feedlots in the United States are located in the southern plains region, which includes areas of the panhandle of Texas up to western Kansas. A majority of cattle finished in these feedlots are sourced within the region. However, there are still a number of calves that come from outside of the region, some of which come from the northern plains, such as cattle sourced from South Dakota. Cattle performance can be influenced by a variety of factors such as stress. Stressed cattle oftentimes have reduced performance compared to cattle that are not experiencing stress (Duff and Galyean, 2007). These incidences of stress can be caused by a variety of factors (weaning, handling, dust, off-feed and water, climate, transportation, etc), and should be avoided if possible (Arthington et al., 2008). However, transportation to feedlots and the intrinsic climate of the regions where feedlots are located cannot be avoided.

Transportation of cattle can induce stress and lead to heightened immune responses, especially when cattle are transported for a long period of time (Arthington et al., 2003; Deters and Hansen, 2020). Transported cattle have also been reported to have slower overall growth following transit (Pritchard and Preston, 1992). The transportation of cattle from one region to another can also cause stress because they have to adapt to the climate of the new region. Weather between regions can be drastically different especially depending on the time of year. Environmental factors and whether cattle are fed in extreme low or high ambient temperatures could impact cattle performance and the competitiveness of feeding cattle between regions (Pritchard and Preston, 1992). Information regarding the relationship between the movement of cattle to regions of different ambient temperature and the degree to which these factors can influence performance is novel and requires further consideration. Therefore, we hypothesized that transporting cattle to a finishing region different than their source of origin will negatively alter feedlot performance compared to cattle of similar origin that were not transported. To test this, we evaluated the influence of region of finishing (SD or TX) and cattle origin (SD or TX) on growth performance, carcass characteristics, and severity and prevalence of liver abscesses in finishing beef heifers.

MATERIALS AND METHODS

Institutional Animal Care and Use Approval

All experimental procedures were approved by the South Dakota State University Institutional Animal Care and Use Committee (IACUC; protocol #2022-1198) and the Texas Tech University IACUC (protocol #A3958-01) and conducted from June 2022 to October 2022.

Cattle Management

Yearling heifers [n = 190; initial body weight (BW) 483 and 425 kg for SD and TX sourced, respectively] sourced within each geographical region were used in a 2 × 2 factorial arrangement of origin state (SD vs TX) and finishing state (SD vs TX). Heifers (n = 98) in the northern plains region were sourced from western South Dakota (SD) and transported approximately 513 km to the Ruminant Nutrition Center (RNC) in Brookings, SD. Similarly, heifers (n = 92) in the southern region were sourced from northwest Texas (TX) and transported approximately 370 km to the Burnett Center in New Deal, TX. In SD, heifers were received in January 2022 (d -188) into concrete pens with bed packs and administered vaccinations against respiratory pathogens (Bovishield Gold FP5 VL5, Zoetis Inc., Parsippany, NJ), *Clostridium* species (Ultrabac 7/Somubac, Zoetis Inc.), and internal and external parasites (Dectomax, Zoetis Inc.). In March (d -130), SD heifers received a Ralgro implant (36 mg zeranol; Merck Animal Health, Madison, NJ). South Dakota sourced heifers were offered a limit-fed high-concentrate ration prior to the study initiation. On d -14, heifers in TX were received in soil-surface pens, administered vaccinations for protection against respiratory pathogens (Myco-B One Dose, American Animal Health, Fort Worth, TX; Bovilis Vista 5Q, Merck), *Clostridium* species (One Shot Ultra 7; Zoetis Inc.), and internal and external parasites (Cydectin; Elanco, Indianapolis, IN). Texas sourced heifers had previously grazed wheat pasture. All heifers received a Revalor-200 implant (200 mg trenbolone acetate and 20 mg estradiol; Merck Animal Health) on d 3. Heifers finished in SD were fed in small pipe and cable pens with concrete bunks and pen floors (7.62 m × 7.62 m, with 7.62 m of bunk space) and heifers finished in TX were fed in soil-surfaced pens (4.9 m × 30.5 m in length, 4.9 m of bunk space).

An allotment BW from d -14 was used to sort heifers into four treatments: heifers sourced from SD and finished in SD (SD-SD, n = 48); heifers sourced from SD and finished in TX (SD-TX, n = 50); heifers sourced from TX and finished in SD (TX-SD, n = 48); heifers sourced from TX and finished in TX (TX-TX, n = 50). Allotment procedures accounted for variations in pen size between finishing locations with 48 heifers in SD-SD and TX-SD treatments and 50 in SD-TX and TX-TX treatments. Transport for SD-TX and TX-SD heifers occurred on d 0. Heifers were transported approximately 1540 kilometers simultaneously without lairage time for 17 h and 18 h for TX-SD and SD-TX heifers, respectively. From d 0 to study end (d 78 for heifers fed in TX and d 90 for heifers fed in SD), heifers were fed a standard grain-based finishing diet common in the respective region (Table 1 for SD finished and Table 2 for TX finished). One heifer from the SD-SD treatment was removed from study on d 55; data from this heifer were included until the time of removal.

Health Measures

Clinical attitude scores (CAS) were recorded on d -1, 0, 1, 2, and 3 to monitor herd health for symptoms of bovine respiratory disease (BRD). These scores were based on a 0 to 3 scale: 0 = normal, 1 = mild bovine respiratory disease, 2 = moderate bovine respiratory disease, and 3 = severe bovine respiratory disease (Love et al., 2014).

Vaginal temperature probes were inserted into heifers to record continuous temperature to monitor stress response in heifers that were transported or not transported, without adding additional stress to the cattle from handling or presence of humans (Burdick et al., 2012). Probes were inserted into all heifers that were transported (50 from SD-TX and 46 from TX-SD) and a portion of the cattle that remained at their respective state of origin for finishing (34 from SD-SD and 30 from TX-TX). Data loggers that had fallen out or did not record data were not included in the data set. Stationary temperature loggers were placed inside each semi-truck and at each finishing location to monitor fluctuations in temperature that may influence heifer vaginal temperatures.

Weather Measurement and THI Estimation

Climatic variables (ambient temperature, relative humidity, and wind speed) were obtained every 30 minutes from a weather station located near the RNC and Burnett Center prior to and throughout the experimental period (June 2022 through October 2022). The temperature-humidity index (THI) was calculated using the formula: THI = 0.81 × ambient temperature + [relative humidity × (ambient temperature – 14.40)] + 46.60 (Hahn, 1999b). The Livestock Weather Safety Index (LCI, 1970) classifications for heat stress include: $\leq$ 74 = normal; 75 $\leq$ THI $\geq$ 78 = alert; 79 $\leq$ THI $\geq$ 83 = danger; and $\geq$ 84 = emergency. Therefore, a baseline average THI value of 75 was used to determine when cattle were experiencing high ambient temperature loads.

Growth Performance

All heifers were weighed on d -1, 3, 15, 28, 56, 78 (TX finished heifers only), and 90 (SD finished heifers only). SD-TX and TX-SD heifers were also weighed on d 1 following transport to their respective finishing location to determine transportation shrink.

Samples for microbial analysis were collected during these timepoints and the results are discussed by Dornbach et al., (2023). Heifers finished in SD were on feed for an additional twelve days because of staging availability at the commercial harvest abattoir. Period performance measures were calculated between weigh days. Cumulative growth performance was based upon body weight (BW) from d -1 (with a 4% pencil shrink applied to account for digestive tract fill) and the final BW (shrunk 4%). Average daily gain (ADG) was calculated as the difference between BW and initial shrunk BW, divided by the days on feed for the respective period; feed efficiency was calculated from ADG divided by dry matter intake (DMI). DMI as a percentage of BW was calculated from BW divided by the average DMI.

Carcass Characteristics

On d 79 and 90 for TX-TX SD-TX and SD-SD and TX-SD, respectively, heifers were shipped from their finishing location in the afternoon to a commercial harvest abattoir near (233 km or 185 km for SD and TX finished, respectively) the finishing location. Heifers were harvested the following morning and carcass data was collected after approximately 24 h of chilling. Hot carcass weight (HCW) was immediately recorded following the harvest procedure. Video image data was collected from the harvest facility for ribeye area, 12th rib fat, and USDA marbling scores. Yield grade (YG) was calculated according to the USDA regression equation (USDA, 2017). Dressing percentage was calculated as HCW divided by the final BW with a 4% shrink. Estimated empty body fat (EBF) percentage and final BW at 28% EBF (AFBW) were calculated from carcass traits (Guiroy et al., 2002) and the retail yield (RY) was calculated from the equation to determine the proportion of closely trimmed boneless retail cuts from the round, loin, rib and chuck of a carcass (Murphey et al., 1960). Liver abscess severity and prevalence was recorded according to the Elanco Liver Scoring System: normal (no abscesses), A- (1 or 2 small abscesses or abscess scars), A (2 to 4 well organized abscesses less than 2.54 cm. diameter), or A+ (1 or more large active abscesses greater than 2.54 cm. diameter with inflammation of surrounding tissue).

Statistical Analysis

The experimental design was a 2 × 2 factorial arrangement of state of origin and state of finishing. For CAS and body temperature data, individual animal was designated as the experimental unit. Pen was considered the experimental unit when evaluating growth performance and carcass characteristics. The GLIMMIX procedure of SAS 9.4 (SAS Inst., Cary, NC) was used to evaluate growth performance, carcass traits, and multinomial data, with fixed effects of source of origin and source of finishing and their interaction. The MIXED procedure of SAS was used for temperature data analysis with time included as a repeated measure. The Kenward Roger adjustment was used to correct the degrees of freedom for unequal experimental units per treatment. Least squares means were separated using the Tukey option in the LSMEANS statement of SAS. A $\alpha \leq 0.05$ was considered significant and tendencies were discussed at $0.05 < \alpha \leq 0.10$.

RESULTS

Health Measures and Temperature Data

Clinical attitude score data can be viewed in Table 3. On d -1 and d 2, there were no treatment differences ($P > 0.05$) in the distribution of CAS. On d 0, there was a shift in the distribution ($P = 0.05$) of CAS towards more scores of 1 and 2 in the TX-TX heifers compared to all other treatments, which had a score of 0. On d 1, TX-TX and SD-TX heifers had a greater shift in the distribution (*P* = 0.02) towards scores of 1 and 2 compared to TX-SD and SD-SD heifers, with SD-SD heifers presenting a CAS of 0. On d 3, all treatments had a CAS of 0 and 1, but TX-TX heifers had a greater proportion (*P* = 0.03) of heifers with a CAS of 1 compared to TX-SD, SD-TX, and SD-SD heifers.

There was a treatment × time interaction ($P \leq 0.01$) for heifer vaginal temperatures during transit (Figure 1). Vaginal temperatures began recording at time of placement on d -1. Transit temperature includes temperatures recorded approximately one hour prior to shipment (timepoint 0) up until both SD-TX and TX-SD heifers arrived at their respected finishing location (timepoint 1260). Vaginal temperatures were increased ($P \leq 0.05$) during time of handling and loading for the TX-SD (timepoint 45, 0445 h) and SD-TX (timepoint 165, 0645 h) heifers. In general, transported heifer temperatures remained lower ($P \leq 0.05$) compared to heifers that were not transported. SD-TX heifer temperatures increased ($P \leq 0.05$) after timepoint 645. Temperatures of heifers remaining in their state of origin began to rise ($P \leq 0.05$) at approximately timepoint 495) and reached a peak at approximately timepoint 960 (SD-SD) and timepoint 975 (TX-TX). Temperatures of heifers that were transported increased ($P \leq 0.05$) again following unloading and handling for TX-SD (timepoint 1065; 2145 h) and SD-TX (timepoint 1245; 0045 h) heifers.

There was a treatment × time interaction ($P \leq 0.01$) for heifer vaginal temperature data post-transit (Figure 2). Post-transit temperature includes temperatures recorded approximately one hour prior to SD-TX and TX-SD heifer feedlot arrival (timepoint 0) up until all treatments were handled to remove the temperature probes (timepoint 3600). In general, vaginal temperature data of heifers followed the circadian rhythm of each day.

Following arrival to each finishing location, temperatures of heifers that were transported (SD-TX and TX-SD) were lower ($P \leq 0.05$) on d 1 compared to heifers that were not transported and were different ($P \leq 0.05$) compared to their counterparts being finished in the same state. By d 2, heifers finished in the same state had similar ($P > 0.05$) vaginal temperatures, and cattle finished in TX had lower ($P \leq 0.05$) vaginal temperatures compared to cattle in SD.

The average temperature humidity index (THI) can be observed in Figure 3. A THI baseline of 75 was used to determine if cattle were experiencing high ambient temperatures. The THI in TX remained above the established threshold level for approximately a month following study initiation without deterring below that level. The THI in SD varied throughout the duration of the study. Overall, heifers finished in TX were exposed to elevated THI above the established threshold level for 54% of the finishing period and heifers in SD were exposed to elevated THI above the established threshold level for 18% of the feeding period.

Growth Performance

Growth performance responses can be found in Table 4. Initial BW and d -1 BW within state of origin were similar (6.51 and 6.28%, respectively; $P > 0.05$) but differed between state of origin ($P \leq 0.01$). Post-transit BW was different ($P \leq 0.01$) between SD-TX and TX-SD heifers, but transit shrink between the two treatments was similar ($P > 0.05$). There was a state of origin × state of finishing interaction for d 3 BW and d 4 to 15 BW, ADG, DMI, gain efficiency, and DMI as a percentage of BW. BW on d 3 and d 15 were different ($P \leq 0.01$) among all treatments (SD-SD > SD-TX > TX-TX > TX-SD). SD-SD heifers gained less ($P \leq 0.01$) compared to TX-SD heifers, which also gained less ($P \leq$

0.01) compared to heifers finished in TX, which were similar ($P > 0.05$). SD-SD heifers consumed less feed ($P \leq 0.01$) compared to TX-TX heifers but consumed more feed ($P \leq 0.01$) than transported heifers (TX-SD and SD-TX), which were similar ($P > 0.05$). TX sourced heifers were less efficient ($P \leq 0.01$) compared to SD-TX heifers but were more efficient ($P \leq 0.01$) than SD-SD heifers. SD finished heifers consumed less feed as a percentage of their BW ($P \leq 0.01$) compared to TX-TX heifers but consumed more ($P \leq 0.01$) compared to SD-TX heifers.

There was a state of origin × state of finishing interaction for d 16 to 28 BW, ADG, DMI, and DMI as a percentage of BW. BW on d 28 were different ($P \leq 0.01$) among all treatments (SD-SD > SD-TX > TX-TX > TX-SD). TX-SD heifers gained less ($P \leq 0.01$) compared to TX-TX heifers but similar ($P > 0.05$) to SD sourced heifers, which were not different than TX-TX. SD-TX and TX-SD heifers consumed similar ($P > 0.05$) amounts of feed but ate less ($P \leq 0.01$) compared to SD-SD heifers, which also ate less ($P \leq 0.01$) than TX-TX heifers. SD sourced heifers consumed feed at a similar ($P > 0.05$) percentage of BW but were less ($P \leq 0.01$) than TX-SD heifers, which were also less ($P \leq 0.01$) than TX-TX heifers.

There was a state of origin × state of finishing interaction for d 29 to 56 BW, DMI, and gain efficiency. TX-SD heifers weighed less ($P \leq 0.01$) than heifers finished in TX, which were similar ($P > 0.05$). Heifers finished in TX were lighter ($P \leq 0.01$) compared to SD-SD heifers. SD-TX heifers consumed less ($P \leq 0.01$) feed compared to all other treatments which were similar ($P > 0.05$). TX-SD heifers gained more efficiently ($P \leq 0.01$) compared to all other treatments, which were similar ($P > 0.05$). There were no state of origin × state of finishing interactions for ADG or DMI % of BW. However, heifers sourced from SD had decreased ($P \leq 0.01$) ADG compared to heifers sourced from TX. Heifers finished in SD had increased ($P \leq 0.01$) ADG compared to heifers finished in TX. Heifers sourced from TX consumed more ($P \leq 0.01$) feed as a percentage of BW compared to heifers sourced from SD. Heifers finished in TX consumed less ($P \leq 0.01$) feed as a percentage of BW compared to heifers finished in SD.

There were no state of origin × state of finishing interactions for the d 57 to Finish period, except for final BW. SD-SD heifers had the heaviest ($P < 0.01$) final BW compared to TX-SD, SD-TX, and TX-TX which were all similar ($P > 0.05$). Heifers sourced from SD had decreased ($P \leq 0.01$) ADG and DMI compared to heifers sourced from TX. Heifers finished in SD had increased ($P \leq 0.01$) ADG and DMI compared to heifers finished in TX. Heifers sourced from TX consumed more ($P \leq 0.01$) feed as a percentage of BW compared to heifers sourced from SD. Heifers finished in TX consumed less ($P \leq 0.01$) feed as a percentage of BW compared to heifers finished in SD.

There was a state of origin × state of finishing interaction for cumulative DMI, cumulative gain efficiency, and cumulative DMI as a percentage of BW. SD-TX had lower ($P \leq 0.01$) cumulative DMI compared to SD-SD, TX-SD, and TX-TX heifers, which were similar ($P > 0.05$). SD-SD heifers had reduced ($P \leq 0.01$) cumulative feed efficiency compared to TX-SD, SD-TX, and TX-TX heifers, which were similar ($P > 0.05$). Cumulative DMI as a percentage of BW was different ($P \leq 0.01$) among all treatments (TX-TX > TX-SD > SD-SD > SD-TX). Cumulative ADG was similar ($P > 0.05$) among all treatments, however TX sourced cattle had increased ($P = 0.01$) ADG compared to SD sourced heifers.

Carcass Characteristics

Carcass measures are located in Table 5. There was a state of origin × state of finishing interaction for HCW, 12th rib fat, marbling, calculated YG, retail yield, EBF, AFBW, USDA YG, and USDA QG. SD-SD heifers had heavier ($P \leq 0.01$) HCW and AFBW and greater ($P \leq 0.01$) 12th rib fat compared to SD-TX, TX-SD, and TX-TX heifers, which were all similar ($P > 0.05$). SD-SD heifers had increased ($P \leq 0.01$) marbling scores compared to TX-SD and SD-TX heifers, which were similar ($P > 0.05$), and TX-TX heifers, which were similar to SD-TX heifers ($P > 0.05$). Calculated YG and EBF were similar ($P > 0.05$) between TX-TX and SD-TX heifers, but were lower ($P \leq 0.05$) than TX-SD heifers, which were also lower ($P \leq 0.05$) compared to SD-SD heifers. Retail yield was similar ($P > 0.05$) between TX-TX and SD-TX heifers but was increased ($P \leq 0.05$) compared to TX-SD heifers, which was also increased ($P \leq 0.05$) compared to SD-SD heifers. TX-TX and SD-TX heifers had a shift ($P \leq 0.01$) in the distribution of USDA YG towards a greater proportion of YG 1 and 2 carcasses compared to TX-SD and SD-SD heifers; SD-SD heifers had a shift ($P \leq 0.01$) in the YG distribution with more YG 4 carcasses. TX-TX and SD-TX heifers had a shift ($P \leq 0.01$) in the distribution of USDA QG with more USDA Select carcasses compared to SD-SD and TX-SD heifers, which had a greater ($P \leq 0.01$) proportion of premium choice and USDA Prime carcasses. Dressing percent (DP) and ribeye area (REA) were similar ($P > 0.05$) among treatments. However, SD sourced heifers had increased ($P \leq 0.01$) DP compared to TX sourced heifers. Heifers finished in TX had larger ($P \leq 0.01$) REA compared to heifers finished in SD. Liver abscess prevalence and severity was also similar ($P > 0.05$) among treatments, but there was a tendency ($P = 0.10$) for TX sourced heifers to have a greater shift in the distribution towards more abscessed livers compared to SD sourced heifers.

DISCUSSION

Health Measures and Temperature Data

CAS were recorded to observe cattle for BRD symptoms (Love et al., 2014). One heifer from the TX-SD treatment was treated for symptoms of BRD and had a CAS of 3 on d 2. The heifer was treated with a tulathromycin injection (Draxxin KP at 2.5 mg/kg of BW; Zoetis; Kalamazoo, MI) and observed for additional symptoms in a hospital pen. The heifer was returned to her home pen the following morning with no further symptoms. It is important to note that the environmental temperature in TX was 41.7°C (26.1°C low) and in SD was 36.1°C (25.6°C low) on the day of transit (d 0). The following day (d 1), the environmental temperature in TX was 40°C (25.6°C low) and in SD was 31.1°C (18.3°C low). Cattle finished in TX appeared to be more susceptible to increased CAS. This is most likely caused by the increased temperatures cattle in this region were experiencing during this week. Overall, the observed CAS did not indicate threats of concern for BRD.

It is important to note that all vaginal temperatures of heifers were in an normal body temperature range (37.5 to 39.5°C) for cattle (Church, 1988). Vaginal temperatures have been suggested to provide more accurate and less variable temperatures as opposed to rectal temperatures (Lees et al., 2018). In general, heifers that were transported had lower vaginal temperatures compared to non-transported heifers. Whereas vaginal temperatures of heifers that were not transported increased throughout the day, likely due to heat of fermentation following the morning feeding (NASEM, 2016). Similar to Burdick et al., (2012), transported heifer temperatures in the present study were increased during times of loading, unloading, and handling. Interestingly, the temperatures of the SD-TX heifers began to increase at timepoint 660 min; this corresponds with the approximate time that the semi-truck transporting cattle to TX reached western Kansas. It was at this point in the journey that the external temperature was approximately 40°C, according to data retrieved from a stationary temperature logger placed inside the semi-truck transporting the heifers. THI values during transit were 78 and 75 for TX and SD, respectively. Increased rectal temperatures were observed at increasing THI values (Kim et al., 2023), which may help explain this increase in vaginal temperatures following the increase in environmental temperature throughout the day. Vaginal temperatures of SD-SD cattle were the highest during the transit time period and post-transit time period. SD sourced cattle were also further along in their compositional growth curve, which may better explain the increased vaginal temperatures.

Increased THI values have been shown to have a positive correlation with incidences of heat stress in beef cattle (Mader, 2003). The severity of heat stress events may be more apparent if cattle that are exposed to increased thermal conditions during the day are unable to experience nighttime cooling (Lockard et al., 2020). In the present study, cattle finished in TX had elevated THI values for 54% of the feeding period compared to cattle finished in SD that only experienced elevated THI for 18% of the feeding period. A majority of the time when the elevated THI values were observed in cattle finished in TX was during the first month of the study. It was during this time that the average THI did not fall below the threshold level of 75, whereas in SD the average THI values during this time was below the threshold level for most of the time. Zimbelman et al., (2009) re-evaluated the THI value in which high producing lactating dairy cattle began experiencing symptoms of heat stress and determined that production was reduced starting at a THI value of 68 as opposed to 72. Perhaps high producing beef cattle also experience this same effect and THI threshold levels below 75 should be considered. Although no heat stress measures in this study were recorded, it is possible that cattle finished in TX could have been stressed to a greater degree compared to their counterparts in SD. This is especially important to consider as susceptibility of heat stress will likely increase as genetic selection continues to drive genetic productivity (Bernabucci et al., 2010).

Growth Performance

The authors speculate that most of the differences in growth performance measures within period were likely attributed to compensatory growth measures. Compensatory growth has been defined as a period of faster or more efficient rate of growth following a period of slower or less efficient rate of growth that could result from nutritional or environmental stress of planned management strategies (NASEM, 2016). In the present study, both sets of cattle had experienced prior planned nutritional management strategies with TX sourced heifers grazing wheat pasture and SD sourced heifers limit-fed a high-concentrate ration. Authors acknowledge that differences in backgrounding management is a limitation to this study, but it does provide a realistic scenario of cattle sourced from each respective region.

Pritchard (1996) described compensatory growth as influencing two production characteristics: increased DMI compared to animals of the same BW and improved feed efficiency. The effects of this mechanism are especially apparent in the d 4 to 15 period where the TX-SD, SD-TX, and TX-TX heifers had improved feed efficiency compared to the SD-SD heifers. These differences were driven by reduced ADG with increased DMI for the SD-SD heifers. The reduced gains are partially biased due to a management decision in SD to feed the SD-SD heifers to gain approximately 1.36 kg daily in attempt to extend the days on feed for the SD-SD heifers. In the following period (d 16 to 28), there were no differences in feed efficiencies between treatment groups. The efficiencies observed from d 4 to 15 are partially due to the recovery of growth following transit for the SD-TX and TX-SD heifers as described by Pritchard and Preston (1992). Still, the TX-TX heifers had improved feed efficiency during this time, and a numerical improvement from d 16 to 28. This could be explained by the heifers originating from TX provided a lower plane of nutrition compared to SD sourced heifers (Drouillard et al., 1991). Prior to the initiation of this study, TX sourced heifers likely had reduced energy requirements for maintenance grazing wheat pasture compared to the SD sourced heifers being limit-fed a high concentrate ration, which led to an enhanced increase in energy available for gain due to the increased DMI (Drouillard et al., 1991; Pritchard, 1996).

Since the cattle were transported equal distances for similar durations, it is not surprising that shrink did not differ between TX-SD and SD-TX heifers. It was suggested by Self and Gay (1972) that cattle transported an average of 1023 km have 7 to 9% shrink and require approximately 10 d to recover shrink lost during transportation. In the present study, heifers had 6.28 and 6.51% shrink for TX-SD and SD-TX heifers, respectively. Since the cattle in the present study were yearlings and did not appear to be highly stressed as opposed to newly-weaned calves (Coffey et al., 2001), this could help explain the lesser degree of shrink in heifers transported 1540 km. By d 15, heifers in both treatments had recovered the transportation shrink, with TX-SD heifers weighing the same as d -1 and SD-TX heifers weighing 10 kg more than on d -1. This would also explain the magnitude of increased average daily gain during the d 4 to 15 period for both of these treatments.

The growth recovered following transit has been termed recovered growth (Pritchard and Preston, 1992). It is evident that heifers did regain the growth lost during transit within 15 d, with SD-TX heifers weighing similar to the SD-SD heifers. However, the TX-SD heifers were lighter than the TX-TX heifers. At the initiation of the study, BW were similar within source of origin but different between sources, so it is not surprising that there are differences in BW throughout the study between origin source. However, after d 15, SD-TX heifers never statistically weighed similar to the SD-SD heifers and after d 28, SD-TX heifers never weighed statistically more than the TX-TX heifers. It was at this point that shipping heifers to higher ambient temperatures resulted in reductions in overall performance of the SD-TX heifers, as evidenced by reduced ADG and DMI. This was likely a response to heat stress during this time , as heat stress has been demonstrated to reduce performance (St-Pierre et al., 2003). When observing the final BW at the end of the study between cattle of similar origin, the SD-TX cattle weighed approximately 45 kg less than the SD-SD heifers. Whereas the TX-SD heifers finished 2 kg heavier than the TX-TX heifers. However, the SD finished cattle did have an additional twelve days on feed. If we assume cattle finished in TX gained similarly in the last period with an additional twelve days, it would decrease the magnitude in BW differences between the SD-SD and SD-TX heifers (622 vs 594 kg, respectively), but increase the magnitude between TX-TX and TX-SD heifers (607 vs 587 kg, respectively). Unfortunately, due to the availability at the packing plants in each region during this time it was not possible to harvest at the same days on feed, and authors realize this is a limitation to this study.

Carcass Characteristics

There is limited research investigating the influence of transit to varying environments on carcass characteristics, as most research has been evaluated shortly following the transit period. It is likely that the basis of variation in growth performance is further observed in carcass measures and is a function of the differences observed between the different types of backgrounding systems and types of cattle and the additional twelve days on feed, as mentioned previously. In general, cattle coming from a lower plane of nutrition will finish leaner and at lower percentages of empty body fat at equal days on feed (Hogg, 1991; Pritchard, 1996). These concepts were observed in the present study where the SD sourced cattle finished fatter compared to the TX sourced cattle.

Authors also believe observed carcass measures may be attributed to the transportation into differing ambient temperature environments. Baumgard and Rhoads (2013) suggested that cattle can lose body mass during times of heat stress due to increased need of glucose for the immune system and increased losses due to respiration during these events. Cattle therefore have an increased maintenance requirement, resulting in less intake energy available for gain. In the present study, SD-TX cattle had lighter and leaner carcasses compared to the SD-SD heifers. This is likely a result of the phenomenon discussed by Baumgard and Rhoads (2013). There is also increased lipolysis during heat stress events, as the immune system requires more glucose to maintain homeostatic conditions. This could explain a possible glucose sparing event that occurred in the cattle finished in TX, as these heifers had significantly reduced marbling scores and quality grades compared to their counterparts finished in SD. Heifers finished in TX also had increased REA compared to heifers finished in SD. Perhaps the increase in REA may be partially attributed to the nutrient prioritization in the hierarchy of tissues (van Milgen and

Noblet, 2003; Baumgard and Rhoads, 2013). This influenced the differences in YG and RY as greater proportions of lean tissue result in lower numerical yield grades at the same level of rib fat with similar carcass weight (USDA, 2017). SD-SD heifers had increased RF which could contribute to increased EBF. Based on the results of the present study, it appears that cattle finished in higher ambient temperatures resulted in improved yield grades, but also had lower quality carcasses, with only 3% of the carcasses finished in TX grading premium choice or better. On the other hand, cattle finished in lower ambient temperatures had improved carcass quality but reduced cutability. As previous research has indicated that the ideal amount of 12th rib fat needed to allow for optimal marbling is approximately 1.27 cm (Bruns et al., 2004; Maddock, 2013), it does not appear that the twelve fewer days on feed hindered the TX finished cattle to accumulate sufficient rib fat.

Another mechanism could play a role in the fact that the TX-SD cattle had 26% of the carcasses grade premium choice or better with 24% USDA Select, compared to 0% premium choice or better with 63% USDA Select carcasses for the TX-TX cattle. These differences may be explained by the variations in the finishing diets between regions, which was done to have diets remain common for each region. It has been reported that cattle fed a steam flaked corn diet compared to a dry-rolled corn based diet had larger REA and greater rib fat, but lower marbling scores and quality grades (Owens and Gardner, 2000). These findings are consistent with the results observed in the present study. The changes in carcass composition would reflect a shift in the site of digestion from the rumen (steam flaked corn) to the small intestine (dry-rolled corn), resulting in increased subcutaneous fat deposition from less ruminal dietary starch for steam flaked corn (Owens et al., 1997). This mechanism could explain the differences between cattle finished in different regions with differing corn processing methods.

Overall, all treatments had less liver abscesses compared to plant averages (≤ 23% vs 30.8%, respectively) reported in the 2016 National Beef Quality Audit (Boykin et al., 2017). This also coincides with previous research suggesting feedlot heifers in generally have less liver abscess prevalence compared to feedlot steers (Grimes, 2022). Heifers sourced from SD tended to have lower liver abscess prevalence and severity compared to heifers sourced from TX. This is consistent with previous research indicating cattle in the northern plains region have lower incidence of liver abscess compared to those in the southern plains region (Grimes, 2022). Cattle sourced and/ or finished in SD also had numerically greater proportions of normal livers compared to cattle sourced and finished in TX. The TX-TX heifers were fed steam-flaked corn for the entire duration of the study, which has been associated with greater incidence of liver abscesses compared to cattle fed dry-rolled corn (Nagaraja and Lechtenberg, 2007), which likely explains the differences observed. Still, cattle sourced from SD had numerically greater proportions of normal livers overall compared to cattle sourced from TX. This is interesting as SD sourced cattle were fed a limit fed high concentrate diet (primarily dry-rolled corn based) from January until the initiation of the study in July, where they were either continued to be fed dry rolled corn or fed steam-flaked corn. Perhaps liver abscess prevalence is also dependent on the type of cattle and region where they are sourced from.

IMPLICATIONS

Collectively, growth performance appeared to be influenced by the conditions of backgrounding experienced by the cattle (TX sourced heifers off wheat pasture vs SD sourced heifers coming from grow yard with limit-fed high concentrate-based ration). In addition, heifers transported from low ambient temperatures to high ambient temperatures may see increased incidence of heat stress. This seemed to influence overall carcass merit. However, this may also be partially caused by SD finished heifers being on feed for an additional twelve days. The type of processed grain (steam-flaked corn vs. dry-rolled corn) fed during the finishing phase may also influence performance and carcass quality. Thus, further investigation is needed to conclude if transportation and/ or ambient temperatures and the type of grain processing affect feedlot performance and overall carcass value in finishing cattle sourced and finished in different regions of the United States.

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Table 9.1. Diet composition of heifers fed in South Dakota for 90 d[1].

	d 1 to 7		d 8 to 12		d 13 to 35		d 36 to 90	
Item	SD-SD	TX-SD	SD-SD	TX-SD	SD-SD	TX-SD	SD-SD	TX-SD
Dry Rolled Corn[2], %	48.03	39.24	48.02	48.02	60.09	60.09	69.36	69.36
Corn Silage, %	32.17	32.64	32.16	32.16	20.53	20.53	-	-
Oatlage, %	-	-	-	-	-	-	10.00	10.00
Grass Hay, %	-	8.05	-	-	-	-	-	-
Dried Distillers Grain Solubles, %	14.87	15.07	14.89	14.89	14.12	14.12	15.33	15.33
Liquid Supplement[3], %	4.93	5.00	4.93	4.93	5.26	5.26	5.31	5.31
Dry Matter, %	54.56	54.33	54.58	54.58	63.25	63.25	77.99	77.99
Crude Protein, %	13.52	13.54	13.52	13.52	13.54	13.54	14.31	14.31
Neutral Detergent Fiber, %	23.50	28.22	23.50	23.50	19.41	19.41	17.78	17.78
Acid Detergent Fiber, %	12.31	15.39	12.31	12.31	9.64	9.64	8.79	8.79
Ether Extract, %	4.52	4.35	4.52	4.52	4.52	4.52	4.71	4.71
Ash, %	2.85	3.46	2.85	2.85	2.49	2.49	2.79	2.79
Net energy of maintenance, Mcal/kg	1.92	1.82	1.92	1.92	1.98	1.98	2.01	2.01
Net energy of gain, Mcal/kg	1.29	1.21	1.29	1.29	1.35	1.35	1.37	1.37

[1] SD-SD = heifers that originated from South Dakota and were finished in a feedlot in South Dakota; TX-SD = heifers that originated from Texas and were finished in a feedlot in South Dakota.

[2] Ground corn + MGA 200 premix replaced a portion of DRC (0.5 lb/hd/d premix) to include MGA at 0.50 mg/heifer daily.

[3] Liquid supplement (all values except DM on a DM basis): 69.04% DM, 41.86% Crude Protein, 38.38% NPN, 0.43 Mcal/lb NEm, 0.30 Mcal/lb NEg, 23.00% TDN, 0.91% Crude Fat, 0.43% Crude Fiber, 10.89% Ca, 0.32% P, 7.00% K, 0.22% Mg, 6.03% NaCl, 3.07% Na, 0.33% S, 4.23 ppm Co, 199.88 ppm Cu, 11.99 ppm I, 6.84 mg/lb EDDI, 83.16 ppm Fe, 304.81 ppm Mn, 2.90 ppm Se, 664.59 ppm Zn, 19,987.55 IU/lb Vit A, 199.88 IU/lb Vit E, and 579.35 g/ton Monensin Sodium.

Table 4.2. Diet composition of heifers fed in the Texas for 78 d[1].

	d 1 to 12		d 13 to 17		d 18 to 22		d 23 to 78	
Item	TX-TX	SD-TX	TX-TX	SD-TX	TX-TX	SD-TX	TX-TX	SD-TX
Steam Flaked Corn[2], %	61.99	20.35	61.99	34.66	61.99	49.62	61.99	61.99
Sweet Bran, %	27.5	55.91	27.5	45.23	27.5	34.96	27.5	27.5
Alfalfa, %	6	19.67	6	15.52	6	10.19	6	6
Limestone, %	2.51	1.98	2.51	2.59	2.51	2.53	2.51	2.51
Supplement[3], %	1.5	2.09	1.5	2	1.5	2.04	1.5	1.5
Urea, %	0.5	---	0.5	---	0.5	0.66	0.5	0.5
Dry Matter, %	76.90	80.10	76.90	71.4	76.90	76.60	76.90	76.90
Crude Protein, %	13.3	17.3	13.3	16.6	13.3	14.8	13.3	13.3
Neutral Detergent Fiber, %	19.3	29.9	19.3	30.8	19.3	23.5	19.3	19.3
Acid Detergent Fiber, %	8.2	16.5	8.2	17.1	8.2	12.9	8.2	8.2
Ether Extract, %	3.0	2.5	3.0	2.4	3.0	2.6	3.0	3.0
Ash, %	4.8	11.6	4.8	10.7	4.8	8.7	4.8	4.8
Net energy of maintenance, Mcal/kg	2.25	1.90	2.25	1.90	2.25	2.12	2.25	2.25
Net energy of gain, Mcal/kg	1.54	1.21	1.54	1.21	1.54	1.43	1.54	1.54

[1] SD-TX = heifers that originated from South Dakota and were finished in a feedlot in Texas; TX-TX = heifers that originated from Texas and were finished in Texas.

[2] Ground corn + MGA 200 premix replaced a portion of DRC (0.5 lb/hd/d premix) to include MGA at 0.50 mg/hd/d

[3] Vitamins and minerals met or exceeded NASEM (2016) requirements for finishing beef heifers and included monensin sodium at 30 g/ton. Supplement supplied 5.99% potassium chloride, 44.40% crude protein, 3.82% sodium, 8.34 mg/kg cobalt carbonate, 395.00 mg/kg copper sulfate, 408.00 mg/kg iron sulfate, 764 mg/kg manganous oxide, 2.92 mg/ kg selenium, 2,490.00 mg/kg zinc sulfate, and 30 g/ton monensin sodium (Rumensin 90; Elanco Animal Health, Greenfield, IN) on a DM basis. Actual diet formulation based on weekly DM determinations.

Table 4.3. Effect of source of origin (SD vs TX) and finishing location (SD vs TX) on heifer clinical attitude scores (CAS[1]) prior to and following transit[2].

Day	CAS	SD-SD	SD-TX	TX-SD	TX-TX	Org × Fin
d -1	0	100.0	100.0	82.6	80.4	0.83
	1	0.0	0.0	17.4	15.2	
	2	0.0	0.0	0.0	2.2	
	3	0.0	0.0	0.0	2.2	
d 0	0	100.0	100.0	100.0	76.1	0.05
	1	0.0	0.0	0.0	19.6	
	2	0.0	0.0	0.0	4.3	
d 1	0	100.0	92.0	97.8	80.4	0.02
	1	0.0	6.0	2.2	15.2	
	2	0.0	2.0	0.0	4.4	
d 2	0	100.0	90.0	95.6	89.1	0.52
	1	0.0	6.0	2.2	8.7	
	2	0.0	4.0	2.2	2.2	
d 3	0	97.9	96.0	93.5	92.6	0.03
	1	2.1	4.0	6.5	17.4	

[1] CAS recorded on d -1, 0, 1, 2, and 3 with a 0 to 3 scale: 0 = normal, 1 = mild bovine respiratory disease, 2 = moderate bovine respiratory disease, and 3 = severe bovine respiratory disease.

[2] SD-SD = heifers that originated from South Dakota and were finished in a feedlot in South Dakota SD-TX = heifers that originated from South Dakota and were finished in a feedlot in Texas; TX-SD = heifers that originated from Texas and were finished in a feedlot in South Dakota; TX-TX = heifers that originated from Texas and were finished in Texas.

Table 4.4. Effect of source of origin (SD vs TX) and finishing location (SD vs TX) on cumulative growth performance responses[1].

		Treatment[2]					*P*-Value	
Item	SD-SD	TX-SD	SD-TX	TX-TX	SEM	Origin	Finish	Org × Fin
Pens, n	6	6	5	5	-	-	-	-
Heifers, n	48	46	50	46	-	-	-	-
Initial BW (d -14), kg	483	425	483	425	-	-	-	-
d -1 BW, kg	480	438	478	430	4.1	0.01	0.08	0.34
d 1 BW, kg	-	411^{a}	449^{b}	-	3.6	-	-	0.01
Transit shrink, %	-	-6.28	-6.51	-	0.419	-	-	0.60
d 3 BW, kg	480^{d}	414^{a}	454^{c}	437^{b}	3.6	0.01	0.57	0.01
d 4 to 15								
BW, kg	495^{c}	437^{a}	488^{c}	468^{b}	3.8	0.01	0.01	0.01
Average daily gain (ADG), kg/d	1.34^{a}	2.06^{b}	2.95^{c}	2.70^{c}	0.200	0.10	0.01	0.01
Dry matter intake (DMI), kg	9.59^{b}	8.48^{a}	9.78^{b}	10.65^{c}	0.173	0.36	0.01	0.01
G:F	0.14^{a}	0.24^{b}	0.34^{c}	0.25^{b}	0.021	0.04	0.01	0.01
DMI % of BW	1.94^{b}	1.94^{b}	2.00^{a}	2.28^{c}	0.030	0.01	0.01	0.01
d 16 to 28								
BW, kg	520^{d}	458^{a}	511^{c}	498^{b}	4.1	0.01	0.01	0.01
ADG, kg/d	$1.87^{a,b}$	1.60^{a}	$1.79^{a,b}$	2.31^{b}	0.235	0.44	0.07	0.02
DMI, kg	10.14^{b}	9.69^{a}	9.17^{a}	11.00^{c}	0.191	0.01	0.20	0.01
G:F	0.19	0.17	0.19	0.21	0.023	0.91	0.10	0.27
DMI % of BW	1.95^{a}	2.12^{b}	1.92^{a}	2.35^{c}	0.038	0.01	0.19	0.01
d 29 to 56								
BW, kg	564^{c}	519^{a}	547^{b}	545^{b}	5.7	0.01	0.33	0.01
ADG, kg/d	1.56	2.19	1.27	1.66	0.147	0.01	0.01	0.26
DMI, kg	11.34^{b}	12.03^{b}	10.04^{a}	11.89^{b}	0.362	0.01	0.01	0.02
G:F	0.14^{a}	0.18^{b}	0.13^{a}	0.14^{a}	0.011	0.01	0.01	0.04
DMI % of BW	2.01	2.32	1.84	2.18	0.051	0.01	0.01	0.36
d 57 to Finish[2]								

BW, kg	622^{b}	587^{a}	577^{a}	585^{a}	6.0	0.01	0.33	0.01
ADG, kg/d	1.72	1.98	1.39	1.84	0.081	0.01	0.01	0.26
DMI, kg	11.97	13.16	10.12	11.94	0.402	0.01	0.01	0.27
G:F	0.14	0.15	0.14	0.15	0.010	0.10	0.91	0.44
DMI % of BW	1.92	2.24	1.75	2.04	0.055	0.01	0.01	0.64
Cumulative								
ADG, kg/d	1.63	1.99	1.65	1.97	0.054	0.01	0.96	0.71
DMI, kg	10.76^{b}	10.84^{b}	9.78^{a}	11.37^{b}	0.242	0.01	0.20	0.01
G:F	0.15^{a}	0.18^{b}	0.17^{b}	0.17^{b}	0.004	0.01	0.25	0.01
DMI % of BW	1.73^{b}	1.85^{c}	1.69^{a}	1.94^{d}	0.032	0.01	0.17	0.01

[1] A 4% pencil shrink was applied to all BW measures to account for gastrointestinal tract fill.

[2] SD-SD = heifers that originated from South Dakota and were finished in a feedlot in South Dakota SD-TX = heifers that originated from South Dakota and were finished in a feedlot in Texas; TX-SD = heifers that originated from Texas and were finished in a feedlot in South Dakota; TX-TX = heifers that originated from Texas and were finished in Texas.

[3] Final body weights measured either at d 79 for SD-TX and TX-TX and at a d 90 for TX-SD and SD-SD

[a,b,c,d] Means within a row without a common superscript differ ($P < 0.05$).

Table 4.10 Effect of source of origin (SD vs TX) and finishing location (SD vs TX) on heifer carcass trait responses[1].

	Treatment[2]					*P*-value		
Item	SD-SD	TX-SD	SD-TX	TX-TX	SEM	Origin	Finish	Org × Fin
Hot Carcass Weight, kg	404^{b}	367^{a}	369^{a}	364^{a}	4.8	0.01	0.01	0.01
Dressing Percent[3], %	64.9	62.4	63.9	62.2	0.44	0.01	0.07	0.23
Ribeye Area, cm sq	92.84	90.13	99.23	98.52	1.903	0.20	0.01	0.45
12th Rib Fat, cm	1.78^{b}	1.35^{a}	1.30^{a}	1.30^{a}	0.069	0.01	0.01	0.01
Marbling[4]	621^{c}	458^{b}	$417^{a,b}$	385^{a}	18.3	0.01	0.01	0.01
Calculated Yield Grade[5]	3.53^{c}	2.93^{b}	2.40^{a}	2.36^{a}	0.123	0.01	0.01	0.01
Retail Yield[6], %	48.50^{a}	49.94^{b}	51.16^{c}	51.26^{c}	0.300	0.01	0.01	0.01
Empty Body Fat[7], %	33.59^{c}	29.68^{b}	28.55^{a}	28.27^{a}	0.460	0.01	0.01	0.01
Adjusted Final Body Weight[7], kg	572^{b}	546^{a}	557^{a}	552^{a}	8.1	0.01	0.27	0.01
Yield Grade Distribution, %								
1	0.0	6.5	28.0	23.9		0.03	0.01	0.01
2	29.8	60.9	58.0	56.5				
3	55.3	30.4	14.0	19.6				
4	14.9	2.2	0.0	0.0				
Quality Grade Distribution, %								
Select	2.1	23.9	36.0	63.0		0.61	0.01	0.02
Low Choice	19.2	47.8	58.0	37.0				
Premium Choice	46.8	26.1	6.0	0.0				
Prime	31.9	2.2	0.0	0.0				
Liver Abscess Severity and Prevalence[8], %								
Normal	91.5	84.8	88.0	78.3		0.10	0.33	0.94
A-	6.4	8.7	8.0	10.9				
A+	2.1	6.5	4.0	10.8				

[1] Heifers finished in SD were on feed for 90 d and heifers finished in TX were on feed for 78 d.

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[2] SD-SD = heifers that originated from South Dakota and were finished in a feedlot in South Dakota SD-TX = heifers that originated from South Dakota and were finished in a feedlot in Texas; TX-SD = heifers that originated from Texas and were finished in a feedlot in South Dakota; TX-TX = heifers that originated from Texas and were finished in Texas.

[3] DP = (HCW/final BW shrunk 4%) × 100.

[4] 300 = slight^{00} 400 = small^{00} 500 = Modest^{00} 600 = Moderate^{00}

[5] According to the regression equation described by USDA (1997).

[6] As a percentage of HCW according to Murphey et al. (1960).

[7] Calculated according the equations described by Guiroy et al. (2002).

[8] According to the Elanco Liver Scoring System: Normal (no abscesses), A- (1 or 2 small abscesses or abscess scars), A (2 to 4 well organized abscesses less than 1 in. diameter), or A+ (1 or more large active abscesses greater than 1 in. diameter with inflammation of surrounding tissue).

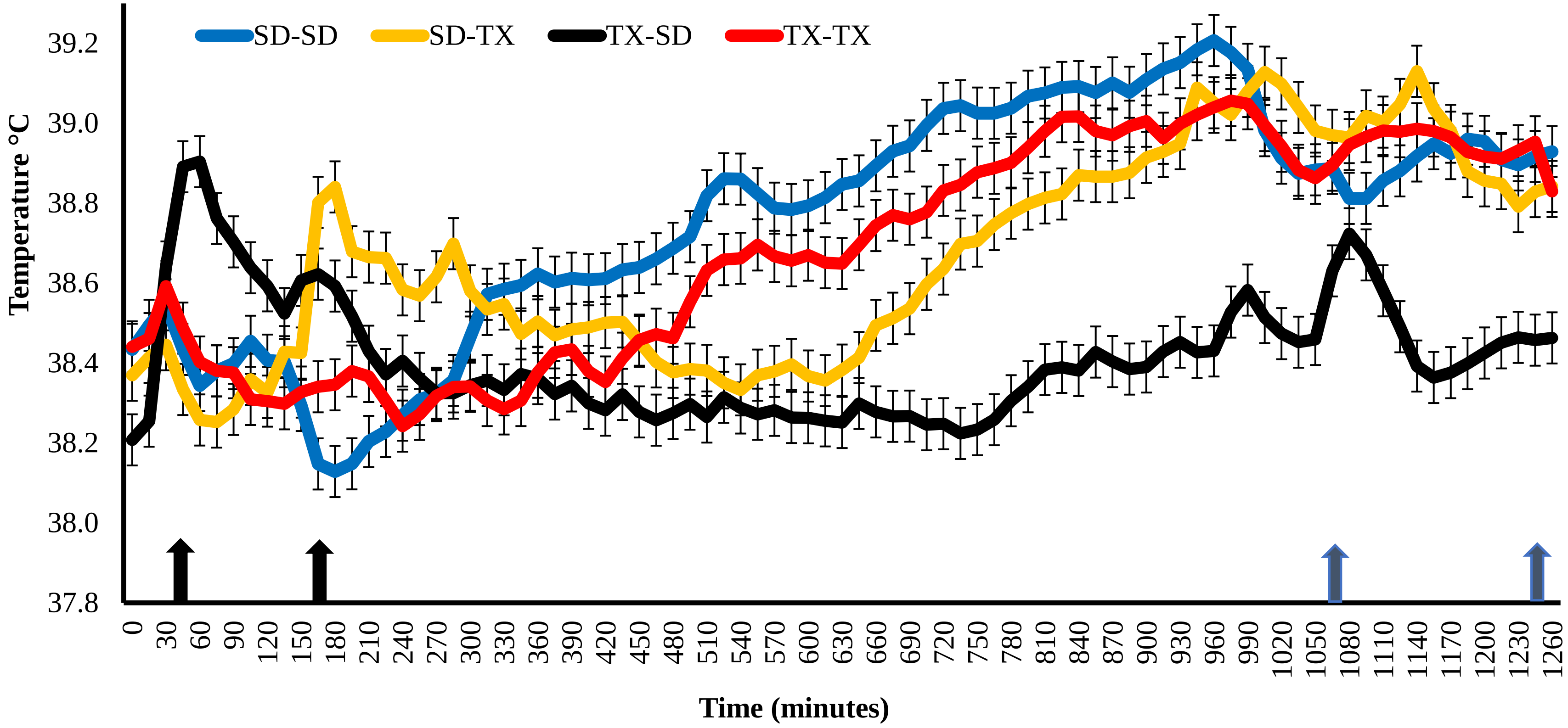

Figure 4.1. Vaginal temperatures during transit of heifers that remained in their state of origin (SD-SD or TX-TX) or were transported to another state for finishing (SD-TX or TX-SD). SD-SD = heifers that originated from South Dakota and were finished in a feedlot in South Dakota SD-TX = heifers that originated from South Dakota and were finished in a feedlot in Texas; TX-SD = heifers that originated from Texas and were finished in a feedlot in South Dakota; TX-TX = heifers that originated from Texas and were finished in Texas. Trmt × Time, Trmt, and Time (P = 0.01). Timepoint 0 was 4:00 am on 7/19/22. Timepoint 45 was when TX-SD heifers were shipped (4:45 am) and timepoint 165 (6:45 am) was when SD-TX heifers were shipped (black arrows). Timepoint 1065 was when TX-SD heifers arrived at SDSU (9:45 pm) and timepoint 1245 (12:45 am) was when SD-TX heifers arrived at TTU (blue arrows).

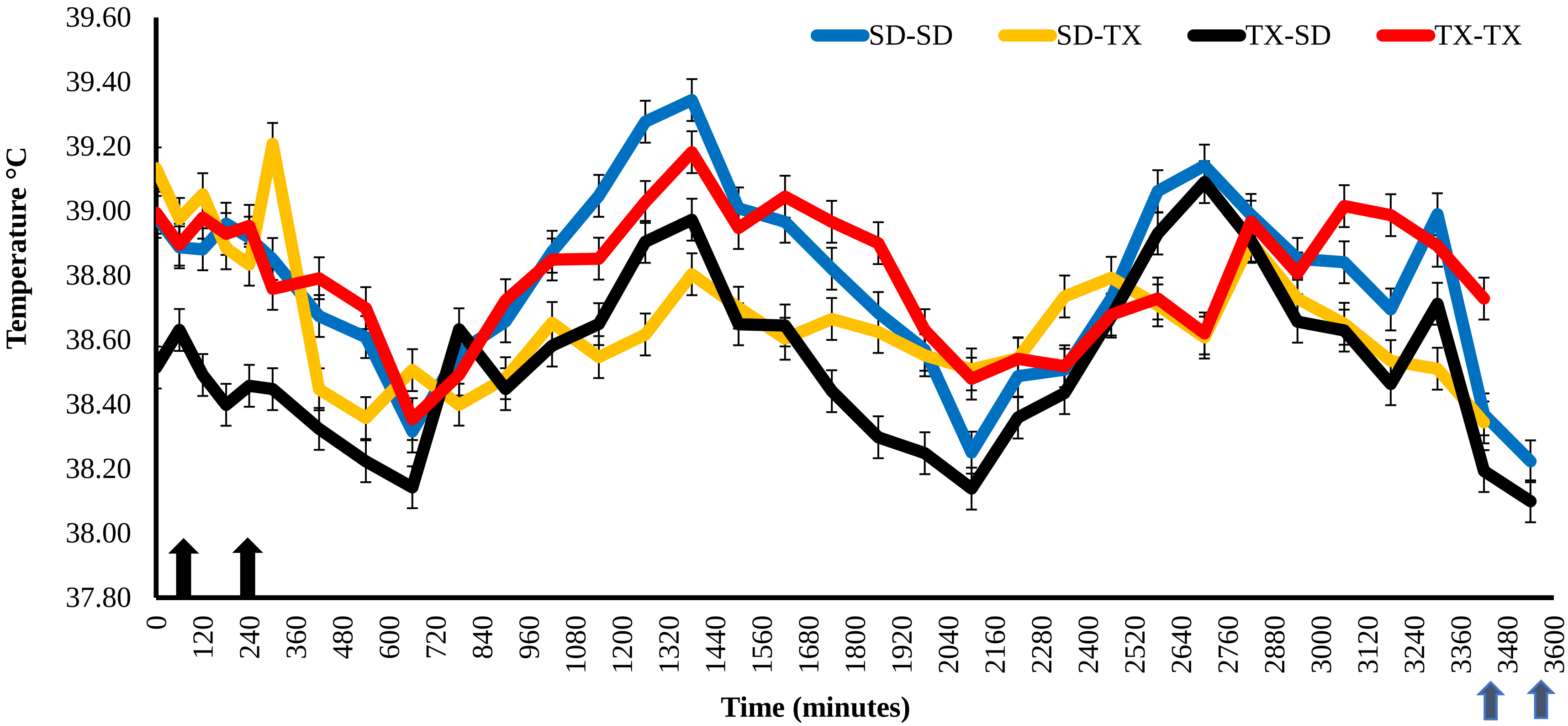

Figure 4.2. Vaginal temperatures post-transit of heifers that remained in their state of origin (SD-SD or TX-TX) or were transported to another state for finishing (SD-TX or TX-SD).

SD-SD = heifers that originated from South Dakota and were finished in a feedlot in South Dakota SD-TX = heifers that originated from South Dakota and were finished in a feedlot in Texas; TX-SD = heifers that originated from Texas and were finished in a feedlot in South Dakota; TX-TX = heifers that originated from Texas and were finished in Texas. Trmt × Time, Trmt, & Time (P = 0.01). Timepoint 0 was 8:45 pm on 7/19/22. Timepoint 60 was when TX-SD heifers arrived (9:45 pm) and were unloaded at SDSU and timepoint 240 (14:45 am on 7/20/22) was when SD-TX heifers arrived and were unloaded at TTU (black arrows). Timepoint 3420 is when cattle at TTU (6:45 am on 7/22/22) were worked to remove temperature probes and timepoint 3525 (7:45 am on 7/22/22) is when cattle at SDSU were worked to remove temperature probes (blue arrows).

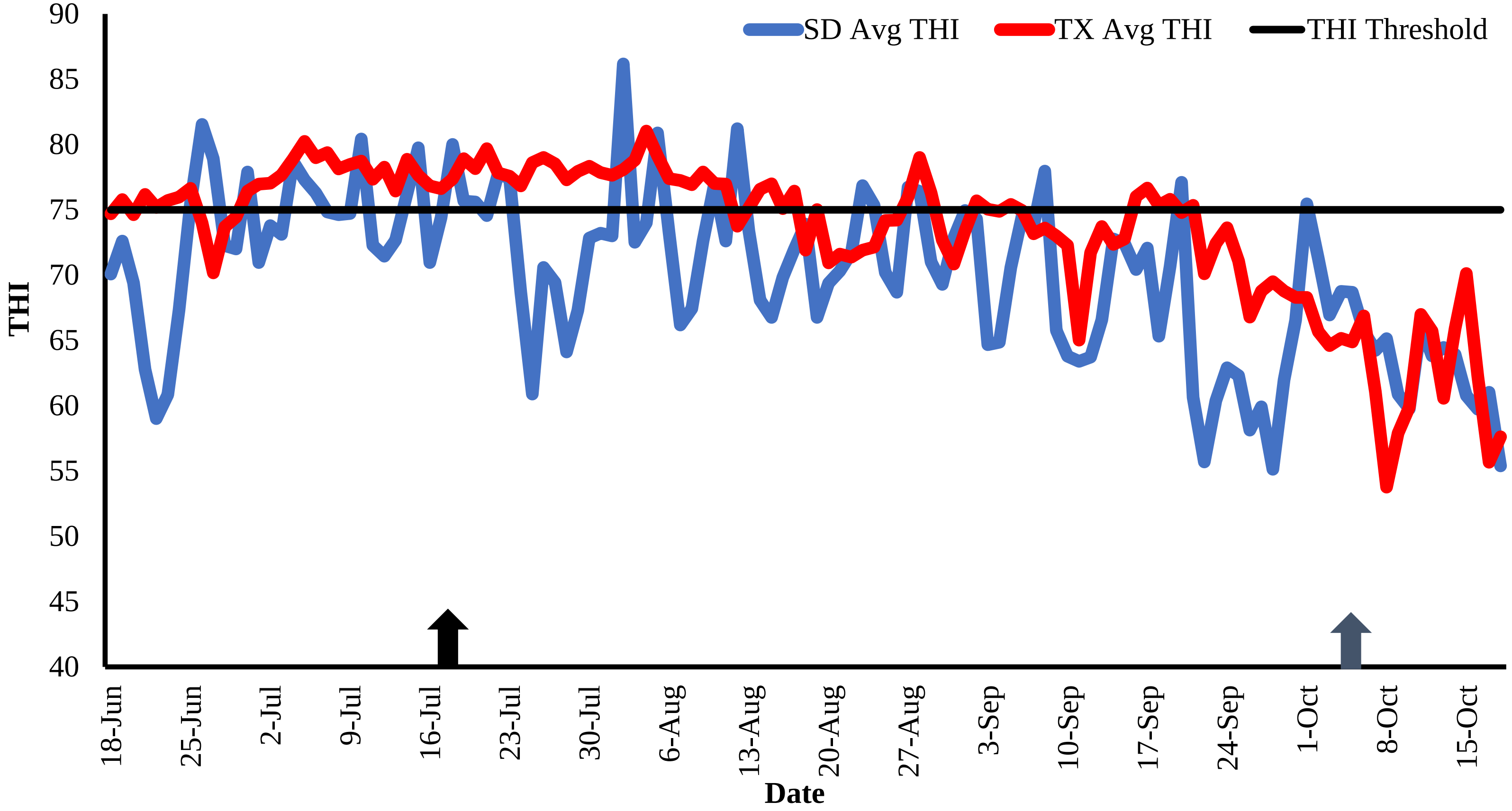

Figure 4.3. Average temperature humidity index (THI) during the feeding period at the Ruminant Nutrition Center in Brookings, SD and at the Burnett Center in Lubbock, TX. THI was calculated as THI = 0.81 × ambient temperature, °C + [relative humidity × (ambient temperature, °C - 14.40)] + 46.40. The black arrow indicates when the study started. The blue arrow indicates when cattle at the Burnett Center in Lubbock, TX were shipped to be harvested. Values above the THI base line of 75 were determined as heat stressed. Cattle in TX were exposed to elevated THI 54% of the feeding period and cattle in SD were exposed to elevated THI 18% of the feeding period.

Chapter V: Dissertation Summation

Beef production is greatly influenced based upon management decisions made in each of its three classical sectors. Decisions made in each sector can influence performance and production in each subsequent sector. These decisions can ultimately influence cattle performance in the feedlot and carcass outcomes. Vaccination of calves in the cow-calf sector can provide calves with sufficient antibody titers if calves were to become immunocompromised during times of stress, such as the weaning event. Having adequate antibody titers to disease pathogens that are known to be associated with the bovine respiratory disease complex can help reduce the threat of this disease and other illnesses. Establishment of proper vaccination protocols can help optimize calf performance in the feedlot.

While cattle are in a backgrounding facility, there are ways to make cattle efficient without additional resources. Having proper bunk management can allow cattle to consume maximal levels of intake at steady rates of gain. Reducing linear amounts of bunk space per head still allows cattle to gain at equal levels as cattle with no restricted bunk space. Net energy equations can be used to program feed cattle to achieve desired rates of gain. Using intake management strategies can be beneficial in monitoring growth in the backgrounding sector.

As cattle are procured from all regions of the United States, this makes transportation an essential component of the beef industry. Transportation can induce stress and can reduce performance, with greater reductions observed during long transit durations. These effects can be further exacerbated when cattle are transported during ambient temperatures. Therefore, it is important to be cognizant of duration and time of year of transit when transporting cattle.

Overall, knowing previous management strategies is beneficial for understanding their influence on cattle performance. Having proper management of cattle throughout each sector can help to optimize beef production.