Extended effects of sequential weaning and backgrounding management in southeastern U.S. beef calves on performance, health, and immunological responses through the feedyard

by

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Abstract

Beef calf management strategies used during the weaning and post-weaning period can have extended effects on growth performance and health in all sectors of the production chain. Understanding post-weaning management strategy impacts on calf performance and health can help producers add value to their operations and further strengthens the viability of the beef supply chain. From an educational perspective, it is important for Extension and industry professionals to understand how post-weaning management strategies are used by beef operations in the Southeast U.S. and the potential success of those practices. The objective of this set of studies was to: 1) determine commonly used calf management strategies in Southeast cow-calf operations and 2) assess the collective effects these practices have on calf health and performance through the feedyard phase. An online survey with 24 total questions was developed and distributed to cattle producers in the state of Alabama. Questions addressed if producers do or do not use managed weaning and backgrounding strategies. A total of 214 complete responses were received with 94% of respondents considering their operation to be a cow-calf operation. Key challenges producers face in their operations who practice managed weaning and backgrounding strategies include input costs, land availability and market predictability. Developing demonstration data models to address the cost-benefit relation of weaning and backgrounding management may help producers evaluate areas of improvement identified in this survey. Extension educators can apply this data to create resources and programs centered on backgrounding to improve the understanding of potential benefits from adequate post-weaning management in beef calves. A two-year study was conducted using 427 steer calves (216 year 1, average BW 297 kg; 213 year 2, average BW 291 kg) from three

Auburn University research farms. Calves were assigned to one of three different weaning method groups for a 14-d experimental period: fenceline, nose-flap, or abrupt weaning. Body weights were collected as a measure of growth performance. Blood samples were collected to measure vaccination and acute phase protein response. After the weaning period, calves were transported to a centralized farm and began a 60-d backgrounding period where they were randomly assigned to one of three nutritional management strategies in a 3×3 factorial design: cool-season annual baleage and 1% BW dried distillers' grains (DDGS), bermudagrass hay and 1% BW DDGS, or grazing mixed warm-season annuals and 1% BW DDGS. Body weights and blood samples were collected throughout the backgrounding period. In both years of the study, fenceline weaned calves had the greatest average daily gain at 1.08 kg/d (P <0.0001) and abruptly weaned calves had the lowest average daily gain losing 0.15 kg/d during the 14-d observation period. In Year 1, steers had a significantly greater (P <0.0001) gain across all treatments than calves in Year 2, with Year 1 calves gaining 7.7 kg more during the weaning period than Year 2 calves. In the backgrounding period, fenceline weaned calves had the greatest average daily gain (P =0.02) in the first 30 d of the backgrounding period regardless of backgrounding diet type. Calves fed the bermudagrass hay-based diet also had a greater average daily (P <0.0001) than both the grazing and baleage diet groups in the first 30 d of backgrounding. From d 30 to 60 of backgrounding in each year, calves on the hay-based diet had the lowest average daily gain (P <0.0001). Steers on both the warm-season annual grazing and cool-season annual baleage diets demonstrated greater average daily gains (P <0.0001) during the last 30-d of the backgrounding period (0.74 kg/d and 0.77 kg/d respectively). Following the backgrounding period steers were transported to a commercial feedyard in Montezuma, KS where they remained for the finishing phase. During this phase performance was tracked through periodic weigh-ins and finally through carcass performance. Results indicate that weaning and backgrounding management strategies may influence calf performance during the transition period into the post-weaning phase.

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War Eagle

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List of Abbreviations

ACTH	Adrenal cortex thyroid hormone
ADF	Acid detergent fiber
ADG	Average daily gain
APP	Acute phase protein
BF	Backfat thickness
BRDC	Bovine respiratory disease complex
BRSV	Bovine respiratory syncytial virus
BVH-1	Bovine herpes virus
BVDV	Bovine viral diarrhea virus
BW	Body weight
CP	Crude protein
CRH	Corticotropin-releasing hormone
CYG	Calculated USDA Yield Grade
DDGS	Dried distillers grains with solubles
DM	Dry matter
ha	Hectare
HCW	Hot carcass weight
HP	Haptoglobin
HPA	Hypothalamic-pituitary-adrenal
IBR	Infectious bovine rhinotracheitis
IFN-y	Interferon- y
kg	Kilogram

IL	Interleukin
MARB	Marbling score
MLV	Modified-live virus
NDF	Neutral detergent fiber
NEFA	Non-esterified fatty acids
NPN	Non-protein nitrogen
PI_3	Parainfluenza virus type 3
PI	Persistently infected
REA	Ribeye Area
RFID	Radio frequency ID tag
RUP	Rumen-undegradable protein
SAA	Serum amyloid A
SNS	Sympathetic nervous system
TDN	Total digestible nutrients
TNF-α	Tumor necrosis factor- α
USDA	United States Department of Agriculture

Chapter 1: Review of Literature

Introduction

The weaning process is widely recognized to be one of the most stressful stages within the life of a beef calf (Roberts, 2020). Following weaning, beef calves are exposed to many different stressors that can have both short and long terms effects on overall performance and economic viability. Due to these compounding stressors, calves often exhibit decreased feed intake, increased vocalization, and immunosuppression, leaving calves susceptible to disease such as bovine respiratory disease complex (Sayre et al., 2019). Cow-calf producers have the opportunity to reduce the amount of stress associated with weaning and post-weaning for calves through different management strategies (Wilson et al., 2017). The concept of the backgrounding sector was developed as a buffer to attempt to combat some of the health issues in weaned calves and increase their body weight (Duff and Galyean, 2007). This sector of the industry provides the industry with a way to advantageously add weight to cattle in a more economical fashion but also helps to adjust the timing and volume of cattle entering the feedyard phase (Peel, 2003).

Impacts of differing management strategies in the backgrounding phase have been extensively studied but very few studies have centered around calves born and raised in the southeast (Lancaster et al., 2014). Calves that are born in the southeast are often at a disadvantage following weaning because of the longer distance they have to travel to the final stage of production (Babcock et al., 2009). But at the same time, southeastern producers have the advantage of ideal weather conditions for almost year-round forage production (Ball et al., 2015). Weaning and post weaning management practices have the potential to influence animal performance throughout its lifetime and can help ease the transition into the next phases of production.

Industry Overview

Cattle production is a key sector of livestock production in the Unites States. In 2022, there were predicted to be 92 million head of cattle and calves in the U.S. accounting for about 17 % of the $462 billion in total cash receipts for agricultural commodities. The United States is the leading producer of beef products in the world contributing 19% of the world supply (Knight, 2019). Beef production can be split into three major production phases including cow-calf, backgrounding (or stocker), and the finishing (or feeding) phase.

Cattle Management Systems in the United States

The cow-calf sector produces weaned calves for further feeding or replacement breeding stock (Gadberry et al., 2016). The two primary animal factors that affect the profitability of cow-calf producers are calf crop percentage and calf weaning weight. Beef calves nurse from their dam for about 6 months of their life before they weaned at around 7 months of age (Peel, 2003). Preconditioning is as a stage in beef production systems to describe weaning, vaccination, and nutritional adaptation of calves at their farm of origin (Lardy, 1998; Lalman, et al., 2010; Wilson et al, 2017; Wells et al., 2019). Following weaning, feeder calves can either go straight into the feedlot phase or enter the backgrounding sector.

The terms “stocker” and “backgrounding” or “preconditioning” are largely used as synonymous terms to describe this sector of the industry (Peel, 2003). Cattle that are placed in a backgrounding system are fed for moderate growth that is often focused on development of muscle instead of fat deposition (Block et al., 2001). Typically, the backgrounding phase takes calves from weaning weight and develops them to yearling weights and prepares them to enter the feedyard for finishing for a 2-to-6-month period of time (Klopfenstein et al., 2000). This sector is important because not only does it allow the industry to utilize resources such as forages to add weight to animals in more advantageous economic conditions, but it also helps by adjusting the timing and volume of cattle that enter the feedyard (Peel, 2003; Gadberry et al., 2016). Management practices during the backgrounding phase are extremely diverse. This diversity in management varies heavily based upon location, resource cost and availability, breed of cattle and more. Backgrounding systems may transition their own cattle from a cow-calf system, or they may purchase weaned cattle for placement in their system (Peel, 2003).

The finishing phase is the final phase before animal harvest. Like in other stages of production, there are several management strategies used to maximize efficiency and profit when cattle are sold to the packer. Cattle are typically in feedyards for 120 to 240 days depending on weight upon arrival (Mathews and Johnson, 2013). Cattle are finished to a target weight range of 1100 to 1400 pounds (Comerford et al., 2013).

Cattle performance is evaluated continuously during each phase of the production chain to determine the marketing and/or harvest end point. Producers often make these management decisions based on seasonal prices of inputs and cattle prices. This seasonal price pattern allows for larger profit during peak demands (Schulz, 2015). At the point of harvest, cattle are sold to a packer where they are evaluated for price on their carcass dressing percentage, USDA Quality Grade, and USDA Yield Grade.

With the opportunity to capitalize on climate conditions for almost year-round forage production, the Southeast United States predominant production system is the cow-calf sector (Drouillard, 2018). In the Southeast, cattle operations are typically smaller on average (45-60 head) and are secondary income sources (McBride and Mathews, 2011). The beef industry is a large sector of agriculture in the state of Alabama, representing a $2.5 billion annually. The cow-calf and backgrounding sectors are the primary components of the beef production cycle represented in the state.

Bovine Respiratory Disease Complex

Bovine respiratory disease complex (BRDC) is a severe disease with many factors contributing to its development in cattle. Diagnosing cattle with BRDC is complicated mainly due to the fact that not all cattle present the same symptoms (Ackermann et al., 2010). The bovine respiratory disease complex is thought to contribute around 60-90% of the morbidity and mortality that occurs in the feedyards (Blakebrough-Hall et al., 2020). However, this disease also contributes to substantial losses in overall animal performance in all stages of production and on the end product in carcass quality (Edwards, 2010). It is currently viewed as the costliest disease in the United States beef industry today (Caswell, 2014).

The pathogenesis of BRDC is defined by stress and unfavorable environmental factors that predispose cattle to pneumonia. It is a complex interaction of environmental, infectious and host factors and although the immune system is prepared to defend the body, these mechanisms are susceptible to a failure as a result of stress, glucocorticoids, and viral infections (Caswell, 2014). Cattle that are born and raised in the Southeast are often at a disadvantage from a disease susceptibility standpoint because 1) most cattle are fed in the Great Plains region of the United States and 2) Southeast U.S. derived cattle have a long journey post weaning to the feedyard. Predisposing factors that often referred to as “stressors” have been suggested to be associated with the development of BRDC (Babcock et al., 2009). These stressors include management practices, transportation, environmental conditions (sudden and extreme changes in temperature), commingling with unfamiliar animals, procedures such as castration and dehorning, along with malnutrition and acute metabolic disorders (Aich, 2009). The disease is usually triggered by a primary viral infection of the upper respiratory tract that predisposes the animal to pneumonia. With a depressed immune system brought upon by the stress of weaning and transportation, cattle are highly susceptible to viral and subsequent bacterial-pathogen infections that result in BRDC morbidity and mortality. Common pathogens associated with BRDC are bovine herpesvirus 1 (BHV-1), bovine viral diarrhea virus 1 and 2 (BVDV 1 and BVDV 2), parainfluenza virus type 3 virus (PI_3), bovine respiratory syncytial virus (BRSV), *Mannheimia haemolytica*, *Pasteurella multocida*, *Histophilus somni* and *Mycoplasma bovis* (Richeson and Falkner, 2020). Viruses and bacteria involved in the development of BRDC act in a synergistic manner, which can result in severe bronchopneumonia and death (Hodgson et al., 2005; Aich, 2009). Viruses predispose the animal's lungs to bacterial infection by causing damage to the respiratory mucosa and lung parenchyma and by inhibiting the animal's defense mechanisms. These promote the activation of virulent factors of bacteria that are normal commensals in the upper respiratory tract (*Mannheimia haemolytica, Pasteurella multocida, Histophilus somni*) of cattle and facilitate lung infection with *Mycoplasma bovis* leading to severe pneumonia (Hodgson et al., 2005). The most important viruses recognized by their association with BRDC morbidity and mortality are Bovine Viral Diarrhea Virus (BVDV), bovine herpesvirus 1 (BHV-1), Parainfluenza 3 virus (PI_3), and Bovine Respiratory Syncytial Virus (BRSV; Baptiste and Kyvsgaard, 2017). Bovine herpesvirus 1, and BVDV 1 and 2 have been previously associated with BRDC (Martin et al., 1999). There are 3 BHV-1 subtypes based on antigenic and genomic differences (BHV-1.1, BHV-1.2a, and BHV-1.2b; Jones and Chowdhury, 2010). Bovine herpes virus infections will lead to an establishment of latency, with recrudescence often occurring in animals that are under stress (Cusack, 2003). Following re-activation in latently infected cattle, BHV-1 has the capability of replicating in mucosal cells, submucosa tissue and in connective tissue near the tracheal rings and therefore is shed greatly in nasal discharges. This could result in acute infection and clinical disease in latently infected cattle and BHV-1 transmission to naïve cattle. The destruction of epithelium of the upper respiratory tract caused by BHV-1 in an acute infection ceases ciliary activity and ultimately leads to secondary bacterial bronchopneumonia.

Bovine viral diarrhea virus is a diverse group of viruses because of the efficiency of the virus to mutate and constantly change. This leads to substantial genetic variation with different genotypes (1 and 2) and subgenotypes (Walz et al., 2010). Based on the genome structure, BVDV can be grouped into two genotypes, BVDV-1, and BVDV-2 each with several subgenotypes. Bovine viral diarrhea virus impairs humoral antibody production, depresses monocyte chemotaxis, and impairs myeloperoxidase antibacterial system in leukocytes (Ridpath, 2010). The most important factor in the pathophysiology and epidemiology of BVDV infection and disease is the ability of the virus to cause persistent infection (PI) of the fetus during gestation. Calves that are born PI with BVDV continually shed the virus increasing the risk of infection of naïve cattle (Walz et al., 2020). Persistently infected animals are more susceptible to disease than their counterparts and are more likely to succumb to fatal illnesses during the first year of life (Ridpath, 2010). Both BVDV and BHV-1 are important contributors to BRDC-associated morbidity and mortality in cattle due to their ability to alter the homeostasis of the upper respiratory tract mucosa and cause severe immunosuppression that leads to secondary and sometimes fatal bacterial bronchopneumonia.

Vaccination against viral and bacterial pathogens associated with BRDC is a common aspect of prevention. Inactive (killed) and active (modified-live-virus) vaccines can be used for the prevention of BRDC. These vaccines commonly include BHV-1, PI_3, and BVDV 1 and 2 antigens. Timing of vaccination varies and can have a significant impact on vaccination efficacy against clinical disease. Making sure that animals are in times of immunologic homeostasis and have time to build up immunity before potentially being challenged with BRDC pathogens (i.e., beef calves after weaning and/or during transport/commingling) is important (Richeson and Falkner 2020). Before arrival at the feedyard, ideally cattle should be vaccinated with at least 2 vaccine doses (initial vaccination and booster vaccination) to give the immune system time to appropriately react and be ready once exposure occurs (i.e., feedyard arrival) (Wilson et al., 2017). The diversity in management strategies and health status of weaning-age beef calves across U.S. cow-calf production systems continues to make it difficult to prevent and treat animals with BRDC during the feeding phase. This has resulted in the massive adoption of metaphylactic treatment of cattle with antibiotics upon arrival to stocker systems and feedyards. This continued use of antibiotics to fight BRDC raises major concerns on the development of multi-drug resistant (MDR) microorganisms ultimately threatening human health (Schneider et al., 2009; Baptiste and Kyvsgaard, 2017).

In 2013, the USDA reported that 16.2% of all cattle placed in a feedyard showed signs of BRDC at some point during the feeding stage and this alarming number BRDC morbidity has not improved in the last 50 years and neither has the mortality rate associated with BRDC (USDA-APHIS, 2019). Data published in 1994 (Vogel and Parrot, 1994) demonstrated that feedyards in the Plains averaged a death loss at 0.128% due to respiratory disease over a 3.5-year period. Vogel et al. (2015) then summarized similar feedyard data showing that BRDC-associated death loss averaged 0.091% of monthly occupancy from 2005-2007 rising to 0.097% in 2008-2010 and to 0.127% from 2011-2013. Published data on death loss comparisons in feedyards over the years report large a variability and a number of contributing factors that could increase BRDC morbidity and mortality: breed differences, animal origins, weather, and differing management styles (Babcock et al., 2009; Caswell, 2014). Importantly it must be acknowledged that the trend of death loss and morbidity in the feedyard due to respiratory disease has not decreased significantly since the turn of the century.

Fighting the BRDC has come at a great cost to the industry. It is estimated that the BRDC-associated costs to the cattle industry are around $800-900 million annually (Caswell, 2014; Theurer et al., 2021). The economic losses associated with BRDC are the consequence of death, treatment, increased labor, and reduced animal efficiency (Brooks et al., 2017). Combating BRDC begins at the cow-calf stage with passive immunity, management, and vaccination. The use of modified-live virus (MLV) multivalent (containing more than one viral and/or bacterial antigen) in weaning-age beef calves has become increasingly common among beef producers in all production stages as a strategy to prevent BRDC. The duration of immunity and efficacy of vaccination of beef calves on reduction of BRDC-associated morbidity and mortality is still inconsistent based on literature reports. (Stokka, 2010; Theurer et al., 2015). In the stocker phase, the health status of purchased cattle is often unknown and in an effort to reduce losses associated clinical BRDC > 90% of stocker producers vaccinate all calves against common respiratory pathogens at arrival; however, management conditions including transport methodologies, delivery systems and diet may play an important role on prevention of BRDC (USDA- APHIS, 2019). Developing a sound system in delivery, focusing on proper nutrition and consistent health programs including vaccination against respiratory pathogens are the prime BRDC-preventive mechanisms for these operations (Sweiger and Nichols, 2010). Feedyards often face similar BRDC morbidity and mortality risks as stocker/backgrounder operations, upon arrival, health status of animals is often unknown and large groups of animals from different origins are comingled often following extended periods (>12 hours) of transport. Operations rely heavily on vaccines and antibiotics as the standard care for BRDC prevention (Edwards, 2010). Even if these preventive strategies reduce the clinical presentation of BRDC, they are not 100% effective and the cost of treatment and reduced performance of animals that develop BRDC usually continues to cause a large economic loss. Holland et al., (2011) reported that feedlot cattle that received at least one treatment for BRDC returned on average $40.64 less than untreated animals and up to $291.93 less if they were treated more than once. Since the 1970s the advancements in vaccines, antimicrobials and preventative technology are a bright point for the beef industry. However, despite these advancements, the prevalence of BRDC has not changed or has maybe increased instead during the last 20 years (Smith et al., 2020). It is important to remember that BRDC is not caused by just a single factor, it is a multifactorial complex and management decisions made in all stages of beef production have an impact on the animal's ability to fight off this disease. In recent years, research has focused on preventative and proactive management strategies for beef calves prior to entering the feedyard and its impact on the health and performance of these animals (Sweiger et al., 2010; Cooke, 2017).

Acute Phase Response and Acute Phase Proteins

The acute phase response provides an early non-specific defense against pathogen challenge through a dynamic process that involves both systemic and metabolic changes in the body (Peterson, 2004). Natural killer cells and other immune system cells (i.e., macrophages, monocytes, neutrophils, dendritic cells, etc.) aid in the activation of immunological responses by stimulating the secretion of proinflammatory cytokines such as interleukin (IL)-1, IL-6, IL-12, tumor necrosis factor-α (TNF- α), and interferon-y (IFN-y) (Carroll and Forsberg, 2007). The cascade of pro-inflammatory cytokines initiates the acute phase response, as well as stimulate other anti-inflammatory mechanisms to regulate the magnitude and effects of acute inflammation. The most notable reaction of the acute phase response is the synthesis and release of acute phase proteins (APP) from the liver, but also includes fever, increases in white blood cells (leukocytosis), lethargy, anorexia, depression and alterations in other plasma proteins and components (Carroll and Forsberg, 2007; Abdallah et al., 2016). The pro-inflammatory cytokines (i.e., IL-1β) stimulate the production of prostaglandins (i.e., PGE2) and regulate the mechanisms that result in an increased body temperature due to an infectious inflammatory response (fever). Furthermore, cytokines induce negative feedback on cytokine gene expression by acting on the pituitary gland and increasing adrenocorticotropic hormone (ACTH) concentrations. The stimulation of ACTH increases the release of cortisol, which is the primary glucocorticoid released by the adrenal cortex. The combined effect of acute inflammation induced by cytokine release and fever ultimately aids in killing pathogens via stimulation of immune cells, as well as by accelerating the enzymatic lytic processes in macrophages and neutrophils (Carroll and Forsberg, 2007).

Acute phase proteins synthesized in the liver by hepatocytes function as proteinase inhibitors, enzymes, coagulation proteins, metal-binding proteins, and transport proteins. The APP can be positively or negatively influenced by proinflammatory cytokines such as IL-1, IL-6, and TNF- α (Abdallah et al., 2016). Acute phase proteins produced by hepatocytes can have both direct and indirect roles in eliciting immune responses. Positive APP increase dramatically in the plasma concentrations in response to infection and cytokine stimulation. Common APP heavily evaluated in research and used as indicators of acute and chronic inflammation in cattle are haptoglobin (HP) and serum amyloid A (SAA; Joshi et al., 2018).

The bovine respiratory disease complex (BRDC) is a severe disease with many factors contributing to its development in cattle. Diagnosing cattle with BRDC in the early stages of the disease is challenging because not all affected animals present with clinical signs of respiratory disease despite having a respiratory infection (Ackermann et al., 2010). Researchers continue to look for better ways to diagnose the disease early and to improve treatment outcomes. Calves with clinical BRDC present a series of different symptoms, including high temperatures, lethargy/depression, decreased appetite, nasal discharge, cough, and abnormal lung sounds. Additionally, the acute inflammatory response induced by infection with respiratory pathogens results in an increase in the concentrations of oxidative stress biomarkers in affected cattle (Schaefer et al., 2012). Studies have shown that acute-phase proteins (APP) may have the potential to be used as diagnostic tools in BRDC diagnosis because their increase during acute inflammation induced by infection with respiratory pathogens (Joshi et al., 2018); however, the specificity of APP for the early diagnosis of BRDC is very low and results from other studies have demonstrated that APP levels are not only elevated in cattle affected with BRDC but also in cattle with traumatic reticulo-peritonitis (hardware disease), mastitis, metritis, and other infectious diseases (Bannikov et al., 2011).

In times of stress and disease, blood concentrations of acute-phase proteins increase as part of the proinflammatory response (Hanthorn et al., 2014). Haptoglobin (HP) and serum amyloid A (SAA) are two of the most extensively studied acute phase proteins in cattle (Abdallah et al., 2016). Both are typically absent when measured in healthy cattle but increase in following viral or bacterial infection in affected animals (Joshi et al., 2018). Haptoglobin eliminates metabolites such as free hemoglobin released from cellular degradation to prevent oxidative tissue damage (Hanthorn et al., 2014). In response to a stress stimulus such as transportation blood concentrations of APPs increase and therefore, APPs are considered good indicators of measuring stress in cattle. Transportation stress is recognized as one of the largest predisposing factors for the bovine respiratory disease complex (Taylor et al., 2010). Haptoglobin has been used to measure stress response in cattle following a travel event (Qiu et al., 2007). Because of its high sensitivity and response to oxidative stress in the body, haptoglobin can be a good indicator of stress and disease and may be used as an aid in the diagnosis of bovine respiratory disease and other infectious diseases or stress related illnesses in cattle (Joshi et al., 2018).

Several studies have previously shown that high plasma concentrations of haptoglobin are negatively associated with the performance of healthy cattle and can be an indicator of acute inflammation or stress (Cooke and Arthington, 2013). Weaning and transport of beef calves are probably two of the most stressful events in the calf's life. The combination of both in a single day as it usually occurs in the majority of southeastern cow-calf production systems can add up on pro-inflammatory responses and immunosuppression increasing the risk of infectious disease such as BRDC (Stokka, 2010; Bhatt et a, 2021). Results from the study of Wottlin et al. (2020) demonstrated a relationship between haptoglobin response, dry matter intake and weight gain. A significant decrease in dry matter intake and weight gain was observed in cattle for 28 days following an increase in HP responses after experimental challenge with *Mannheimia haemolytica*. Growth performance through weight gain is considered to be one of the most critical assessments of stress; sick overly stressed animals do not gain weight successfully (Taylor et al., 2011). Studying HP responses in stressed animals can help to develop management practices that reduce stress through improving the transition of beef calves from the cow-calf farm to the next stage in production.

Stress Response in Beef Cattle

Stress can be described as a reflex reaction that naturally occurs when an animal is exposed to adverse conditions that threaten the homeostasis of such animal (Charmandari et al., 2005). Transportation and other common management practices such as commingling have been identified as important stressors of cattle regardless of their phase in production (Bhatt et al., 2021). When cattle finally reach their destination at the feedyard phase, they not only experience the stress of transport and commingling with other cattle, but they are exposed to a new diet and new and sometimes changing environment increasing stress responses (Holland et al., 2010). The animal's reaction to stress can suppress innate and adaptive immune responses and increase the risk of infectious disease (Wilson et al., 2016). Research continues to show that when cattle become sick and must be treated for disease, performance and profitability of that animal can be affected (Holland et al., 2010; Bhatt et al., 2021).

Commingling

The commingling of cattle from different sources is a common practice in the beef industry as cattle enter into marketing channels and different segments of the production line. Animals can encounter exposure to pathogens and increased incidences of stress at sale barns where cattle are often co-mingled (Duff and Galyean, 2007). Commingling continues to be associated with an increase incidence of BRDC (Alexander et al., 1989; Taylor et al., 2010; Cooke, 2017). Step et al., (2008) concluded that receiving pens with steers from multiple sources had reduced performance and increased BRDC incidence compared to pens with single source steers. While Wiegand et al. (2020) showed that commingling heifers from different sources did not impact their overall performance or BRDC incidence, but increased the re-occurrence of BRDC in this group of animals after the second antimicrobial treatment. Commingling is a stressor that producers often have little to no control of due to the structure of the beef industry marketing system and the small average cow-calf herd size in the United States, especially in the southeast. Research to further explore the impacts of commingling cattle are warranted in all phases of cattle production (Alexander et al., 1989; Ribble et al., 1998; Cooke et al., 2017).

Transportation

Transportation stress occurs for a number of different reasons, but prolonged periods within a small/overcrowded trailer space, close contact with other cattle, and no access to food and water during transport time are probably the most important causes of transport-associated stress. Other factors such as loading/unloading, handling, road conditions, temperature, and ventilation play a role too (Holland et al., 2010; Singh, 2012). Transportation stress can cause a number of different effects on the animal and have a large economic impact on the value of that animal. The most obvious is the loss of body weight. Deprivation of food and water in transport can cause up to a 9% shrink loss in feeder calves (Stanger et al., 2005; Cernicchaiaro et al., 2012). This weight loss is often seen as the largest economic effect in transportation because of the weight-based trading most of our livestock industries are built upon. Transportation events cause stress and immunosuppression affecting immune function and increasing the risk of BRDC in calves (Bhatt et al., 2021). Other important factors during transportation such as handling, loading and unloading of animals can contribute to stress and immunosuppression (Broom, 2008). The stress associated with handling at the time of loading and unloading can vary due to different factors such as the quality of handling, experience of the handler, the temperament of the animal and the quality of the facilities available (Grandin, 2001; Burdick et al., 2010). Transportation stress can also affect carcass and meat quality. Changes in the body due to stress can negatively affect meat color, flavor, and tenderness (Bhatt et al., 2021). During transportation several physiological responses including a rise in body temperature and respiratory rate can occur. The Hypothalamic-pituitary-adrenal (HPA) axis is also triggered along with a rise in the circulating levels of cortisol, glucose and free fatty acids (Carroll and Forsberg, 2007). The HPA axis and the sympathetic nervous system (SNS) are the driving force behind this response for the immune system.

Immune system response

Immunity is defined as an organism's ability to protect itself from a pathogen or toxin. The immune system can be broken down into sections; innate immunity and adaptive (acquired) immunity (Carroll and Forsberg, 2007). Innate immunity consists of barriers, immune cells and other immune factors (i.e., complement) that are present at birth and this type of immunity is unspecific for infectious agents. The innate immune system is the first responder following infection (first 0 to 4 hours after introduction of a pathogen). The innate immune system encompasses physical barriers, and chemical and cellular defenses (Carroll and Forsberg, 2007; Abbas et al., 2015). The physically barriers such as the skin protect the body from invasion. Chemical defenses such as mucous, tears and stomach acid destroy harmful agents whereas innate immune cells engulf and destroy pathogens (Salak-Johnson and McGlone, 2007). The innate immune system identifies pathogen invasion and/or harmful substances (i.e., toxins) that are potentially dangerous and take steps to neutralize or destroy them. This portion of innate immunity is made up of phagocytic cells such as neutrophils, monocytes, and macrophages as well as natural killer cells (Abbas et al., 2015). Innate immunity will also elicit the release of proinflammatory cytokines that control the acute phase inflammatory response, generating fever as well as acute phase proteins (Carroll and Forsberg, 2007). Adaptive immunity is the portion of the system that adapts and builds a response for each specific pathogen that causes infection.

Adaptive immunity is not immediate, nor does it necessarily always last throughout an organism's entire lifespan (Salak-Johnson and McGlone, 2007). This response is broken down into two categories; cell mediated or humoral (Carroll and Forsberg, 2007). Cell mediated immunity will work directly against the pathogen- infected cells, whereas the humoral response generates specific antibodies for a determined pathogen. These responses are characterized by clonal expansion of T and B lymphocytes, generating specific cytotoxic T lymphocytes, and releasing specific antibodies to neutralize or destroy their target antigen, respectively (Carroll and Forsberg, 2007). The first time the body encounters a novel infectious agent its response is known as the primary immune response. In the primary response B lymphocytes, or B cells, produce specific antibodies to the antigen designed to destroy or neutralize it (Salak-Johnson and McGlone, 2007). At the same time, B and T lymphocytes will create memory cells that can detect the pathogen during sequential exposures and respond accordingly. It does take the body time to create antigen-specific antibodies the first time but will be faster to respond in future encounters. The systems work together to help the body return to homeostasis in the fastest way possible. Macrophages and dendritic cells in the innate immune system initiate adaptive immune responses by presenting antigens to naïve lymphocytes in tissues or lymph nodes (Carroll and Forsberg, 2007).

In times of stress such as transportation, acute (short-transport) stress can have an immune-enhancing effect; however, chronic (long-transport) stress can have an immune-suppressing effect (Richeson et al., 2016). Evaluating the effect of stress in all physiologic responses of cattle is challenging to measure or quantify. During transportation stress, the response in the body is initiated and regulated by the HPA axis. During stressful events the hypothalamus releases corticotropin-releasing hormone (or CRH; Weinber and Szilagyi, 2010).

Corticotropin-releasing hormone signals the pituitary gland to secrete a hormone called adrenocorticotropic hormone, or ACTH into the bloodstream (Salak-Johnson and McGlone, 2007). The adrenocorticotropic hormone travels down to the adrenal glands where it prompts the release of cortisol from their cortex, or outer layer. The release of cortisol causes a number of changes that help the body to adapt to stress (Carroll and Forsberg, 2007). For example, it helps to mobilize energy like glucose, so the body has enough energy to cope with a prolonged stressor. When cortisol levels in the blood get high, this is sensed by receptors in areas of the brain like the hypothalamus and hippocampus, which leads to the shutting off of the stress response through what is known as a negative feedback mechanism (Salak-Johnson and McGlone, 2007). At the same time in the central nervous system (CNS) system stimulates sympathetic responses. The adrenal medulla releases epinephrine and norepinephrine into the blood stream. This leads to increase heart rate, increase respiration, increased energy and decrease digestion. This is the body getting ready for fight or flight responses.

As previously mentioned, stress has been shown to be associated with immunosuppressive effects; however, studies have shown that not all stress is immunosuppressive. As shown by Carroll and Forsberg (2007) there may be a bigger difference in immunostimulatory effects caused by acute and chronic stress; whereas acute stress may be immunoenhancing, chronic stress may be immunosuppressive. The immunoenhancing and immunosuppressive effects of stress could happen at the same time, on top of each other creating a stacked affect. Cattle do not have the ability to perceive a stressful situation and respond rationally so prior experiences to events such as transportation can have a large impact on their ability to cope with a repeated exposure to the stressor (i.e., transport). Further research is necessary to continue evaluating management practices that reduce the negative effects associated with weaning, transport and commingling of beef calves.

Weaning and Post Weaning Management

Weaning Management

Beef calves in the United States are commonly weaned from their dams around 7 months of age. This separation from their dam usually occurs abruptly, which can cause extreme stress in the calf often presenting itself in loud vocalization and pacing (Newberry and Swanson, 2008). In addition, there are several physiological responses to weaning including increases in concentrations of plasma cortisol (Lay et al., 2008), norepinephrine (Hickey et al., 2003) and synthesis of acute phase proteins (Arthington et al., 2008). The behavioral and physiological responses associated with weaning have been shown to reduce performance in calves and impair health (Price et al., 2003; Arthington et al., 2008). Weaning stress comes from many different factors including dietary changes, social challenges, new environments, and physical changes as well (Taylor et al., 2010).

Leading up to the time of weaning, a calf's diet typically consists of milk supplied from its dam and maybe a little bit of forage (Pritchard and Burns, 2003). By the time a calf makes it down the production line to the feedyard phase, it must transition from a mostly-milk and forage-based diet to a grain-based diet. This transition does not come easily as beef calves have been observed to be selective eaters, particularly during periods of dietary change (Pritchard and Burns, 2003). As reported by Galyean et al. (1999), dry matter intake by recently weaned calves during the first 2 weeks after arrival was generally less than the needed 1.5% of body weight (BW) daily for maintenance. Other major stressors that occur around weaning can include castration and dehorning. Castration of bull calves in cow-calf operations is a common practice to reduce behavioral problems such as aggression and mounting behavior (Staffor and Mellor, 2005). Calves should be castrated as young as possible to minimize stress and compounding effects (Mullenix et al., 2022). Studies have shown that when castration is conducted prior to weaning, there is adequate time for the animal to recover and avoid the compounding effect of additional stressors (i.e., weaning, transport and commingling) (Bretschneider, 2005). Daniels et al. (2000) reported calves that were castrated at arrival in the feedyard had a morbidity rate of 35.8% and a mortality rate of 3.5% compared to calves castrated prior to arrival (18.6% and 0.0% respectively).

Weaning methods continue to be evaluated on how they impact health and performance of calves. Traditionally weaning involves immediate separation of the calf from their dam followed by immediate shipment and sale (Wilson et al., 2017). Alternative methods to traditional weaning strategies have been the focus of recent research. These methods look to mitigate the stress caused by weaning by easing animals through weaning in steps rather than all at once (Boland et al., 2008). Weaning methods such as fenceline where calves are separated from their dam through a fence and nose-flap where suckling is ceased through a nose device allow weaned calves to have contact with their dams and could reduce stress (Stookey et al., 1997; Haley et al., 2005; Taylor et al., 2019).

Alternative weaning methods have been shown to help ease calves into the next stage of production (Boland et al., 2008). Studies have shown that calves who are allowed fenceline contact with their dams after weaning spend more time eating than calves that are weaned abruptly (Price et al., 2003; Boyles et al., 2007). Price et al. (2003) reported that calves who had fenceline contact with their dams during the weaning phase had a decrease in weight-loss compared to traditional weaning methods. Other studies have shown that weaning may have an impact on feedyard performance. Boyles et al. (2007) found that calves weaned on pasture with fenceline contact to their dams had a decrease in morbidity during the feedyard receiving period. Similarly, Hayley et al. (2005) showed success with a 2-stage weaning process that included the use of nose-flaps for 14 days. Calves were separated from their dams after a period of 14 d with the nose-flaps. After separation, calves in the nose-flap group spent 79% less time walking, and 96% less time vocalizing compared to other groups. Boland et al. (2008) compared fenceline weaning and a 2-stage nose-flap weaning to abrupt weaning. Calves in the nose-flap group gained overall less body weight during the weaning period but at the same time presented reduced serum creatinine kinase and higher non-esterified fatty acids (NEFA) concentrations. Despite the potential benefits of these practices, adoption is relatively low among beef producers in the Southeast U.S. Additionally, applications and carryover effects of these practices into subsequent phases of the beef production chain are relatively limited in the literature.

Backgrounding

Calves generally follow one of two paths following the weaning phase; directly to feedyards before being harvested or being placed in a stocker/backgrounding operation to be grown for a period before heading the feedyard. The term stocker is often used synonymous with backgrounding and preconditioning to describe this sector of the industry (Peel, 2003; Ball et al., 2015). The concept of preconditioning or backgrounding was initially described by Dr. John Herrick in 1965, considering it a pre-arrival practice to help reduce mortality and morbidity in the feedyard by strengthening the animals’ resistance to pathogens (immunity) prior to leaving their farm of origin (Duff and Galyean, 2007; White and Larson, 2009). Backgrounding protocols are not extremely well-defined but often include multiple variations of interventions to help calves become more prepared for the rest of the production phases. Common components of preconditioning include castration and dehorning earlier in life, vaccination, deworming, training to eat from a feed bunk and drink from a water tank and weaning at least 30-45 days prior to shipment (Duff and Galyean, 2007; Taylor, 2010; White and Larson, 2009).

Once calves are weaned, they begin their path to the feedyard that continues to add to the stress that is threating the homeostasis of that animal by being transported multiple times for long distances and being comingled with animals of different origins. Preparing calves for the next stages of beef production is important in all aspects, but especially in the fight against bovine respiratory disease complex (BRDC). Preventative management strategies are an important factor in controlling diseases such as BRDC (Sweiger et al., 2010; Stokka, 2010). Several management practices have been demonstrated to help reducing stress in calves and help preventing stress-related health disorders. Beef calves are usually exposed to different stressful events such as weaning, unfamiliarity with bunk feeding and feed ingredients, transportation, commingling, arrival processing and environmental changes (Cooke, 2017). The diet change is especially drastic for animals coming from the Southeast where forage-based systems are the backbone of cow-calf and stocker operations. The combination of weaning stress, transportation, and commingling negatively affects immune responses and can lead to a high incidence of BRDC (Schneider et al., 2009). Backgrounding programs have become increasingly popular overtime as a management practice to improve calf's health and add economic and viability post weaning. Common components of backgrounding programs include weaning and delayed shipping by remaining on the farm of origin a period of time (15-60 days), a vaccination program, deworming, castration of intact male calves, dehorning, training calves to eat from a bunk and beginning the transition from a forage-based diet to a grain-based diet (Cooke, 2007). These management practices help the calf to cope with stressors prior to weaning while remaining in a familiar environment (Taylor et al., 2019). One of the greatest benefits of backgrounding animals may be the spreading of stressful events over time. Cole (1985) suggested that the major benefit of backgrounding is the spreading and separation of stressors such as castration, weaning, vaccination, transport and marketing over time. Unfortunately, a large portion of this research includes major stressors such as transportation. Several of these studies include calves that have been hauled long distance to the feedyard (>20h; Knowles 1999; Swanson and Morrow-Tesch, 2001; Fike and Spire, 2006).

The backgrounding phase is typically utilized to take calves from weaning weight to yearling weight relying heavily on forages as the predominant component of the diet (Gadberry et al., 2016). These systems are used to prepare slaughter animals on a roughage diet after weaning before they are transitioned to a grain-based diet dependent on their weight and age (Matthews and Johnson, 2013). Producers who background calves typically have different endpoint goals, with some keeping their own weaned calf crops on pasture allowing them to increase BW at a reduced cost. Other producers use this phase to purchase lightweight calves at sale barns and background them to improve not only BW but their health status and appearance to increase market value (Rhineheart and Poore, 2013). Often these systems can be divided into two categories: grazing or confinement. During the backgrounding phase, the goal is typically centered around developing the animal frame and muscle in preparation for finishing in the feedyard, largely utilizing forage-based diets with supplementation of concentrated feeds when needed (Peel, 2003; Johnson et al., 2010). The backgrounding phase is important because of the potential effects on the performance of animals during the finishing period.

Lancaster et al., (2014) conducted a meta-analysis of 40 different research publications that compared several aspects of animal management in the post-weaning phase as well as the subsequential performance in the finishing phase and carcass characteristics. This meta-analysis covered data from over 50 experiments dating back to 1970. In conclusion, the authors found that average daily gain (ADG) during the backgrounding period influenced feedyard ADG, overall feed intake, hot carcass weight (HCW), kidney pelvic heart fat, and ribeye area (REA) but not marbling (Lancaster et al., 2014). Other studies have shown varied results. When comparing calves on different backgrounding diets, Cox-O'Neill et al., (2017) observed differences in the feedyard phase with feed efficiency, ADG, HCW, REA, and marbling score between the management style. Hersom et al., 2004 found no differences in BW gain or efficiency during the finishing phase in animals on differing backgrounding diets. However in this study maintenance energy requirements differed significantly due to forage quality differences across diets. With different management styles across the entire beef industry, further research is still warranted to investigate different backgrounding styles and their impact on the final beef product. There are even fewer studies from the southeastern U.S. where potential for year-round grazing provides producers the opportunity to background calves on a high-quality forage-based systems (Lalman et al., 2010).

Forage based diets in Backgrounding

In the southeastern United States, producers can easily facilitate near year-round grazing for cattle, utilizing both warm-season and cool-season forages. Grazing forages mitigates the need for intensive supplementation strategies and can reduce labor costs (Berthiaume et al., 2006). Producers are often striving to maintain an ADG of approximately 0.68 to 0.90 kg/d over the backgrounding period on forages to help adequately spread costs over productions units to maintain a profit (Ball et al., 2015; Beck et al., 2016). Performance in cattle can vary depending on the selection of pasture that they are placed on after weaning, leading producers to make important management decisions around their forage availability and growing seasons (Coffey et al., 1990). In the southeastern US, there is less of a defined calving season than in other regions of the country largely due to more year-round ideal weather conditions and smaller operation sizes (McBride and Mathews, 2011). But for fall calving seasons, warm-season grass systems can help to provide high yields of good quality forage during the summer months as calves are being transitioned from weaning to backgrounding systems (Hancock et al., 2011).

The perennial forages bermudagrass (*Cynodon dactylon*) and bahiagrass (*Paspalum notatum*) are the most common warm-season forages for cow-calf producers in the Southeast; however, these forages may not always be able to sustain profitable gains in backgrounding animals due to lower quality and decreased digestibility during the mid- to late growing season (Beck et al., 2016). Warm-season annuals such as pearl millet (*Pennisetum glaucum*) and crabgrass (*Digitaria sanguinalis*) have been shown to be highly productive forages that can withstand intense stocking rates and adequately meet growing cattle nutritional requirements (Ball et al., 2015). Warm-season annuals have a shorter growing season but can provide high yields of good quality forage for those shorter periods making them ideal choices for producers with cool-season perennial forages such as tall fescue (*Schedonorus arundinaceus*) as the base of their system (Tracy et al., 2010).

Increase interest has been observed in the Southeast with using crabgrass as a high-quality forage for the summer grazing period (Harmon et al., 2019). Crabgrass was introduced into the United States in 1849 with crabgrass hay being mentioned in experiments for feeding beef cattle as early as the 1890s (Andrae, 2002). Crabgrass is often seen as a weed in turfgrass, hayfields and other crops but crabgrass can be a very productive forage in terms of growth and nutritive value (Ogden et al., 2005; Ball et al., 2015). Crabgrass typically has greater nutritive value than most other warm-season grasses and is highly palatable in the early part of the growing season (Dalrymple et al., 1999). As shown by Ogden et al., (2005), crabgrass can have a crude protein range from 12.0-21.0% with neutral detergent fiber never exceeding 61.9% and acid detergent fiber 31.2% during a growing season with no harvest. It has also been shown to produce more dry matter (DM) accumulation than other popular warm season annuals (Beck et al., 2007). Harmon et al. (2019) showed that across the growing season, crabgrass had the greatest percentage of desirable species in each plot compared to other warm-season annuals in a 3-year study. In the study conducted by Beck et al., (2007) researchers analyzed the change in forage mass and nutritive quality of crabgrass at different harvest intervals (21, 35, and 49 d) compared to other warm-season annuals. Forage mass did increase over the growing season as expected but quality decreased rapidly following the 21-d harvest (Beck et al., 2007). Research on use of crabgrass in backgrounding systems is limited. Boyer et al. (2019) showed gains on crabgrass at 148-275 kg of gain per hectare over the grazing season.

Higher input costs and shorter grazing seasons tend to lead producers to be more hesitant on planting warm-season annuals because of economic profitability (Ball et al., 2015). Warm-season annuals also have an increased risk of stand failure due to increased drought potential during the summer months in the Southeast (Harmon et al., 2019). Further research is warranted in the usage of warm-season annuals in backgrounding systems as feed input costs continue to rise and potential for diversified grazing systems increases.

Stored forage-based diets in backgrounding

With variable climactic conditions, increase in input costs such as fertilizer and fuel and increase in feed prices, producer interest in alternative forage sources such as hay, baleage, and silage has increased. One of those harvest methods, baleage, has become more widely popular in recent years (McCormick, 2013). Baleage, like silage, is fermented and requires an anaerobic environment to ensile. But unlike silage, baleage allows for forage producers to use conventional forage harvesting equipment to cut, condition and bale their forage at approximately 60% moisture, then wrapped in a stretch of wrap plastic which allows for the success of the fermentation process (Ball et al., 2015). The greatest appeal for a producer harvesting baleage, comes for the required curing time for forages is drastically reduced as compared to that of traditional hay production. This allows for producers to harvest forages at their peak quality versus waiting for a wilting time and continue to produce stored forages in increasing erratic weather conditions that can make curing of dry hay more difficult (McCormick, 2013; Han et al., 2014).

The ensiling of baleage is dependent on several factors. There must be a native population of lactic and acetic acid production bacteria present on the plant. Moisture level at wrapping is also a crucial component in baleage production. Recommendations are to wrap bales at approximately 40-60% moisutre for optimum fermentation, lower than 30% moisture does not allow for proper fermentation to occur and higher moisture content can lead to unwanted bacteria activity including increase in butyric acid production (Ball, 2015; Lemus, 2017; Dillard, 2018) At wrapping, once an anaerobic environment has been established, these populations begin to proliferate and become dominant (Muck, 2006). When the forage is harvested, it must be relatively immature with sufficient levels of water-soluble carbohydrates (sugars). As forages mature, cell wall content such as lignin, cellulose and hemicellulose will increase causing the soluble cell contents to decrease. The more immature the forage is, the higher level of fermentable carbohydrates there are and the more optimum fermentation can occur (McCormick, 2013). With an established anaerobic environment and soluble carbohydrates present, the anaerobic environment allows for lactic acid bacteria to become the predominant microbial population (Elferink et al., 2000). Baleage should then be tightly baled and then wrapped as soon as possible with approximately 3 to 6 layers of stretch wrap plastic to achieve the desired anaerobic environment (Ball et al., 2015). If not properly wrapped, exposure to oxygen could prohibit the correct fermentation from occurring and drastically reduce the quality (Bates et al., 1989). All forages ideally can undergo fermentation for baleage production. Cool-season forages typically are more successful in the fermentation process. Warm-season forages have more issues with moisture content due to weather conditions and sugar concentrations are much lower than that of cool-season forages (Bates et al., 1998; Forte et al., 2018). Studies have also indicated that DM at the time of ensiling can significantly affect intake of baleage fed (Thomas et al., 1961a; Charmley and Firth, 2004). Energy is also an important value to consider when building rations around baleage. Baleage is often sufficient in crude protein to support growing cattle, but it is typically in the form of degradable non-protein nitrogen (NPN). Calves will then a readily fermentable energy supplement to support the conversion of NPN into microbial protein (Huntington and Burns, 2007).

Baleage has been extensively studied in feeding to dairy cattle and well as research in feeding silage to growing beef cattle, but research surrounding the use of baleage in backgrounding beef calves is more limited. Berthe et al., (1991) showed wilting bermudagrass 1 to 2 or 3 to 4 hours before baling as baleage increased DM intake as well as improved growing beef cattle performance compared to feeding bermudagrass hay. Martin et al., (2015) evaluated the differences in bermudagrass hay, bermudagrass baleage, and ryegrass-rye baleage with supplement in backgrounding diets for beef calves. Overall, the ryegrass-rye baleage had a slightly higher total digestible nutrients (TDN) value compared to both the bermudagrass hay and baleage. Calves that were fed the ryegrass-rye baleage had higher BW gains than either of the calves on the bermudagrass treatments. The comparison between the two bermudagrass treatments could indicate that simply ensiling the forages does not improve or reduce animal performance (Martin et al., 2015).

Pasture vs. Drylot

Helping cattle begin the dietary transition from more forage-based diets to grain in a preconditioning program may benefit cattle performance upon arrival at the feedyard. However, the true impact of diet type on morbidity during preconditioning remains a heavily discussed topic in research. Fluharty and Loerch (1997) reported that ADG and morbidity of newly received calves were not affected by the proportion of dietary concentrate leading up to the feeding phase. Galyean et al. (1995) indicated that high-quality hay fed ad libitum was associated with a decrease in morbidity compared to a higher concentrate diet in recently weaned calves. In a study conducted by Rivera et al. (2005), the statistical relationship between BRDC and dietary roughage concentration in lightweight, stressed cattle was analyzed. This showed a slight decrease in morbidity as the dietary roughage level increased; however, ADG and DM intake also decreased. After a cost-benefit analysis was performed and showed that decrease morbidity was insufficient to offset greater profit associated with the increased ADG; Rivera and colleagues (2005) concluded that high-concentrate diets were of greater overall benefit to lightweight, stressed calves than forage-based diets.

Supplementation strategies

Over the course of an animal's life, feed costs will represent one of the largest if not the largest expense in beef production systems (Anderson et al., 2005). Producers may have to supplement growing cattle in backgrounding systems for a number of reasons. Oftentimes it can be contributed to the fact that the desired level of animal production is not being achieved from grazed forage alone (Beck et al., 2016). With this shortfall in nutritive value, an energy and/or protein supplement can be used to meet animal needs and boost animal performance.

In 1999 Moore et al. constructed a database to describe the effects of supplementation on cattle consuming forage diets. In this analysis the researchers wanted to better understand the associative effects of supplemental feeds fed in a restrictive manner when forage intake was not limited and voluntary. In summary, the greatest average daily gain (ADG) responses to supplementation occurred in improved, non-native forages with energy supplements (60% TDN or greater) but only when supplemental crude protein intake was greater than 0.05% of BW. There was also variation in ADG response to similar CP amounts of TDN or CP provided by supplements. The greatest responses in average daily gains typically occurred when supplemental energy was provided to calves consuming lower quality forages. In diets with rumen undegradable protein (RUP) supplementation there was a lower increase in ADG for TDN supplementation at a similar level. This could indicate that in most forage settings, protein may be the first limiting nutrient for growing cattle. Moore et al. (1999) also evaluated the effects of supplementation on voluntary forage intake. In this study, researchers found that in general as supplementation rate of calves consuming improved forages increases voluntary forage intake decreases however as the supplementations rate of calves consuming lower quality native forage and residues increases there were instances when forage intake both increased and decreased. The authors attributed this discrepancy in intake response to the TDN:CP in those lower quality forages. With a TDN:CP of 7 or greater, supplementation increased forage intake. This could be attributed to a nitrogen deficiency and in this case the supplemental nitrogen helped to increase microbial efficiency and digestion of forages, this could increase the passage rate and consequently intake. The data analyzed in this report shows that when proteome is not limiting in the underlying forage system, supplementation usually decreases forage intake but this is not simply a 1:1 substitution effect. Moore et al. (1999) demonstrated that this interaction between supplemental feeding options and available forages for growing cattle is a complicated relationship. Then in 2000 Kunkle et al. published another review on designing supplementation programs for cattle that are consuming forage-based diets. Here they reported that the most common supplementation program needs to meet the basic forage diet's protein, mineral and vitamin deficiencies and then provide supplemental energy. All awhile making sure that it results in a positive return over cost. In grazing diets supplementing with energy is typically in the form of either starchy or highly digestible fibrous byproducts. It is important to note that supplementation of energy can have an effect on forage intake as a result of positive (synergistic) or negative (antagonistic) associative effects. When the primary energy substrate provided by the supplement is comprised of starch, then forage intake and digestibility can be decreased (supplement at over 0.4% of BW). Although there are cases in which decreased forage intake might be more favorable, for example in years of decreased forage dry matter yield. Although substitution of forage intake by supplementation can become excessive and cause forage wastage. Finding the best forage/supplementation combination is a challenge producers face in their own individual operations that will not only improve cattle performance but also increase forage utilization and do both in a cost-effective manner (Kunkle et al., 2000). Since both of these publications there has been more research focused in the area of supplementation of growing cattle that are raised in forage-based systems.

Cool season forages typically have more protein and are more energy-dense than warm-season forages (Forte et al., 2018). However, forage analysis is still essential to determine the exact forage nutritive value and growing cattle may still benefit from supplementation. Although supplemental protein may increase forage digestibility and dry matter intake, a starchy or highly digestible fibrous energy feedstuff may help to achieve even greater gains in animal performance as reported by Cappellozza et al. (2014). Supplementation of energy and/or protein supplementation in forage-based systems is common in these operations to achieve these elevated rates of gain and compensate for these changes in forage quality and availability (Drouillard et al., 1999). But with an increase in purchase price of feed ingredients it is important for producers in backgrounding systems to purchase supplementation ingredients at an advantageous price, and the use of by-product or co-product feed ingredients has become more popular in the Southeast (Rankins and Prevatt, 2013). By-product or co-product feeds are often defined as feed ingredients that are secondary products produced in the processing of another product. Common by-products in the Southeast are commonly found from peanut processing, the ginning of cotton, dry and wet milling of corn, fermentation of grains for alcohol, and the extraction of oil from soybeans (Mullenix and Rankins, 2018). These by-products are often used in cattle diets to meet short comings of forages such as protein, energy and fiber needs (Rankins and Prevatt, 2013).

One of the more popular co-product feed ingredients used in the livestock industry today are spent distillers grains. Distillers grains are the result of the production of ethanol from the fermentation of corn, wheat and other grains. Distillers grains are often sold in forms such as we distillers grains, dry distillers grains, wet distillers grains with soluble, and dry distillers grains with solubles (DDGS; Hoffman et al., 2011). Dry distillers grains with solubles have a relatively high fat content and percentage of rumen undegradable intake protein and can be an excellent feedstuff to provide both protein and energy for growing cattle (Kleinschmidt et al., 2006; Wahrmund et al., 2011). Research is extensive when looking at forage-based diets supplemented with DDGS. Corrigan et al. (2009) fed DDGS at increasing levels of 0.25, 0.50. 0.75 or 1.0% of BW to steers consuming a high-quality forage diet. A linear increase in ADG was observed as levels of DDGS supplementation increased. Similarly, Morris et al. (2015) fed DDGS to heifer calves consuming a high- or low-quality forage diet at differing levels of supplementation. Results showed that in both diets, as rate of supplementation increased, ADG increased as well. Both studies observed a decrease in forage intake as supplementation rates increased (Morris et al., 2005; Corrigan et al., 2009). This, however, did not show a dietary substitution effect (Morris et al., 2005). Researchers predict that forage digestibility may have been enhanced as total DMI increased. A similar effect was observed in Smith et al. (2020) with supplementation on calves grazing bermudagrass with various levels of DDGS. Results like the ones observed in Morris et al., (2005), and Corrigan et al. (2009) suggest that the use of energy supplementation such as DDGS could possibly allow for increased stocking rates in grazing situations due to the substitution of supplement for forage (MacDonald et al., 2007).

Over the last decade, price variability of grains has increased; therefore, utilizing cellulosic feeds for as much of the animal’s growth as possible may be a method to increase profitability (Rankins and Prevatt, 2013). Watson et al. (2012) evaluated the effect of three different nutritional management strategies and their effect on performance and profitability of yearling beef steers grazing forages over a 5-year period. Treatment groups included grazed forages, grazed fertilized forage or grazed forage with DDGS supplementation. A variable stocking rate for the three treatments was used to maintain similar residue height among treatments; the stocking rates were 8.53, 12.88. and 13.27 AUM/ha for the control, fertilized and supplemented treatments respectively (Watson et al., 2012). Over the course of 156 d grazing season, supplemented steers gained 0.27 kg/d more than the control and fertilized treatments: resulting in 40 kg heavier BW at the end of the study. With the increased BW and decreased costs associated with pasture inputs, supplementing steers resulted in $23.75/steer greater profit than control steers and $26.26/steer greater than fertilized treatment steers (Watson et al., 2012). When supplementing cattle that are consuming forages, quality matters. Cattle consuming high quality forages, economically beneficial responses to rumen degradable protein or rumen undegradable supplementation alone are often not observed usually due to the high protein levels already present in the forage (Vendramini and Arthington, 2008). However, energy supplementation can lead to increased ADG of calves and possible increased in stocking rates, offsetting some of the costs associated with forage inputs (Watson et al., 2012; Lomas et al., 2017).

CONCLUSIONS

One of the main goals for many animal scientists and producers in the beef cattle industry is finding ways to improve the performance and health of cattle to increase efficiency in all sectors of the industry. By limiting as much stress in the transitional phases such as weaning as possible, we can increase overall performance and health of calves which can then minimize production costs for beef cattle producers. The literature in this area is fairly mature in terms of weaning methods and the understanding of backgrounding systems. But historically, most of this research on calf health and performance has been somewhat segmented or in a component-based approach with even fewer of them being completed in southeastern production settings. Further research is needed to investigate the impacts of integrated southeastern systems and the impact differing management styles can have on weaning, post-weaning the subsequent pre-transport management and on overall calf health and performance through the finishing phase.

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Chapter 2: Assessment of weaning and backgrounding management practices utilized by Alabama beef cattle producers

Introduction

Beef production in the United States can be split into three major production phases: cow-calf, backgrounding (or stocker), and the finishing phase. In the Southeast U.S., the cow-calf sector is the predominant production system with producers having the opportunity to capitalize on climate conditions for nearly year-round forage production (Drouillard, 2018). Cattle production in the state of Alabama represents a $2.5 billion industry (USDA, 2021).

Weaning is one of the most critical and stressful stages in the life of a calf and the transition to the next phase of the production chain can have a major impact on both the short- and long-term health and growth performance of the calf (Taylor et al., 2020). After weaning, feeder calves may go straight into the feedyard phase for finishing or enter the backgrounding sector. Typically, the backgrounding phase takes calves from weaning weight, develops them to yearling weights and prepares them to enter the feedyard for finishing. This sector is important because not only does it allow the industry to utilize resources such as forages to add weight to animals, but it also helps by adjusting the timing and volume of cattle that enter the feedyard (Peel, 2003; Gadberry et al, 2016). The management practices that are utilized during these stages of production can have a large impact on the economic viability and overall calf performance and quality. Even with numerous studies illustrating the potential increase in returns from post-weaning management practices, many cow-calf producers are still hesitant in adoption (Popp et al., 1999; Pope et al, 2011).

With the number of different management strategies that a producer can utilize during these stages of production, periodic characterization of on-farm management practices used by Southeast U.S. cattle producers who do or do not use managed weaning and backgrounding practices may help Extension professionals develop or refine educational strategies for improving adoption. The objective of this study was to determine perceptions, on-farm applications, and potential barriers of adoption of beef calf weaning and backgrounding among Alabama producers.

Materials and Methods

This survey was approved through the Auburn University Institutional Review Board under Protocol # 22-066.

Survey Development and Distribution

An online survey was developed and distributed to evaluate perceptions and applications of beef calf weaning and backgrounding management practices used by Alabama cattle producers. The survey contained 24 total questions (Appendix 1) and was distributed in March in 2022. Questions focused on management strategies on calves pre- and post- weaning including nutrition and marketing decisions. Several questions focused on the barriers some producers might experience in adopting better management practices. However, the total length of the survey for each participant was dependent on the answers to specific questions. At question 10 participants were asked if they background their calves following their weaning period, participants who selected no had three more questions before their survey ended. Participants that stated they background in most or some years had eleven more questions to answer.

The survey was distributed through Qualtrics™ software. Collaboration with state commodity groups (Alabama Beef Cattle Improvement Association, Alabama Cattlemen's Association, Alabama Farmers Federation) and state Extension personnel (County Extension Coordinators and Regional Extension Agents) helped distribute the survey through an online survey response link. These groups sent producer listservs an email with a direct link to the survey. Survey data was also collected through solicitation of responses at in-person commodity group events (n = 2 during March 2022). The survey link was also shared through the Alabama Cooperative Extension System website and affiliated social media pages (Alabama Beef Systems Extension Program and Alabama Forage Focus Program Facebook pages). A total of 214 responses were received by the end of the survey deadline. The resulting 214 responses did come from a more targeted producer group, aimed at producers who are currently involved in state commodity groups or actively participate in extension programming.

Results and Discussion

Demographics of Operations

The 214 survey respondents represented beef cattle operations from across the state of Alabama. Participants were asked to classify their operation as: commercial cow-calf, purebred cow-calf, commercial and purebred cow-calf, stocker/backgrounder, cow-calf and stocker or other. A total of 94% of all respondents considered their operation to be a cow-calf operation of some form. The majority of participants (52%) considered their cattle operations to be a commercial cow-calf operation. Eleven percent of respondents considered their operations to be a purebred cow-calf system, while 17% of respondents considered themselves to be both a purebred and commercial cow-calf operation. Thirteen percent classified their beef cattle operation as both a cow-calf and stocker operation. Stocker operations represented the smallest sector at 6% of respondents.

Forty six percent of respondents indicated they had a smaller size herd of 50 head or less that calve each year (22% at 25 or less and 24% at 26-50 head). A herd size of 51 to100 head represented 28% of respondents, 14% from 101-200 head and 12% indicated they had 200 or more head of cattle. These results follow similar trends reported by McBride and Mathews (2011), where beef cattle production in the Southeast tends to be centered around smaller cow-calf herds that are considered secondary income for farmers. With a diverse landscape of farm size and structure in the cow-calf sector in mind respondents were then asked to rank a series of calf production management considerations and challenges from most-to-least relevant as they applied to their beef cattle operation (Table 1). Table 1 illustrates the top three key challenges producers face are input costs, land availability and market predictability. Mid-level topics were lack of marketing options, sickness, facilities, and labor. Topics of lesser priority included stress of operation and wildlife; these responses were consistently placed at the bottom of the scale of responses. In the Southeast with many operations being part-time businesses, returns may less reliably cover input costs, making these key challenges predictable (McBride and Mathews, 2011; Drouillard, 2018). Beef producers continue to face challenges with fluctuating input costs associated with feed, fertilizer, and other inputs, where USDA (2022) reports some of the highest input costs in a decade with feed prices up 16% since just 2021.

Preweaning and Weaning Management Practices

Almost half of respondents (47%) reported a calving season in the fall (October to December). Twenty-three percent of participants had a winter (January to March) calving season and 19% as a spring season (March to May). There was an 11% response for no defined calving season among producers.

When asked to describe their method of calf weaning, 55% of respondents stated that they abruptly wean and 38% reported that they use fenceline weaning. Five percent of respondents use the nose-flap weaning method. Abrupt weaning is generally considered the more traditional form of weaning for beef cow-calf producers, but alternative weaning strategies have demonstrated a reduction in stress of weaning and subsequently improved overall calf performance (Boland et al., 2008). Methods such as fenceline weaning and nose-flap weaning look to mitigate the stress caused by weaning by easing animals through weaning in steps rather than all at once (Boland, 2008; Taylor et al., 2020).

Producers were asked to share projected outcomes and next steps in the production chain for their bull, steer, and heifer calves each year. Figure 1 illustrates the range of responses to this question and notes several different approaches are used for each category of calves as producers were asked to select all options they followed. With bull calves, one quarter of respondents stated their bull calves are sold at weaning and another 22% of respondents develop them to be sold as breeding stock. Only 13% respondents retain bulls for personal use and 40% stated they do not sell calves as bulls and instead they are castrated as calves. Castration of bull calves is a common practice amongst beef producers to reduce behavioral problems such as aggression and mounting behavior that could result in injuries to the animal (Staffor and Mellor, 2005) and is often a recommended practice associated with the backgrounding phase (Thomson and White, 2005). With steer calves, almost half (44%) of respondents indicated they are backgrounding steer calves, while 29% are selling steers at weaning. Around 23% of respondents retain steer calves after weaning through the finishing phase. For beef heifers, 71% of respondents are retaining and developing heifers with 45% of those producers developing heifers for personal use and the other 26% developing and selling heifer calves as breeding stock. Twenty one percent of respondents sell their heifer calves at weaning and 8% will retain some heifer calves through the finishing phase.

After weaning occurs, 61% of producers indicated that they background their calves. Another 25% stated that they do this in some years but not always. For the respondents that do not background calves, they were subsequently asked why they do not practice backgrounding. Table 2 highlights the main issues producers face when making the decision to background calves or not. Overall, the unpredictability of the market (22%) was the main concern producers face. Facilities, costs, time, and land availability are also a concern for producers. When asked what changes in their programs might encourage them to practice backgrounding management, respondents answered with better facilities, greater time allocation, and price changes in the market. For producers that do not background their calves, the final question asked in the survey was what management practices were observed prior to the sale of their calves. Sixty-six percent of these producers are castrating and 59% are vaccinating their calves prior to sale. Only 19% of producers are implanting before sale (Table 3). These numbers are still higher than previous data reported by the USDA. According to the USDA around 61% of cow-calf operations do not regularly vaccinate their calves (USDA, 2019). The higher response rate in this survey could be attributed to the population of producers targeted.

Postweaning and Backgrounding Management

For the 166 respondents who indicated they background their calves in most years, a series of questions followed about management surrounding this phase of their operation. When asked what their experience with backgrounding calves was, a large majority (77%) of producers responded that they background their own calf crop following weaning. Thirteen percent stated that they purchase calves off farm to background, while 5% of producers stated they custom background calves for others and 5% of producers selected ‘other’. Of these respondents that chose ‘other’, several producers stated they hire someone else to contract background their calves.

Subsequent questions for producers who background their calves focused on management practices used on-farm. When asked what forms of animal identification they use, 95% of the respondents said they utilized plastic ear tags (Table 4). Other forms of identification that are used were tattoos (25%) and electronic ear tags (19%) being the other popular options. Respondents were asked to select all options that applied to their management practices implying that several of these forms of identification are utilized together. It is important to note here that no one selected that they use no forms of identification.

Backgrounding Calf Nutrition Management

Producers who practice backgrounding management were also surveyed on specific nutrition management strategies utilized on their operation. Producers were first asked about forage management strategies. Figure 2 notes that 94 respondents indicated they use rotational grazing within their system, with continuous grazing being the second highest response. When asked if they use conserved forage sources, 76 respondents indicate they always use these resources, whereas 28% indicated that they sometimes use them, illustrating an emphasis on grazed forages. Warm-season perennial grasses, such as bermudagrass (*Cynodon dactylon*), bahiagrass (*Paspalum notatum*), and dallisgrass, (*Paspalum dilatatum*; 75%) were the most widely used in backgrounding programs with cool-season annuals being the second most utilized. Two-thirds of producers reported that they regularly soil test their pastures whereas only

31% of respondents indicated that they regularly have their forage sources tested for nutritional value. Using a forage analysis can not only help to make soil management decisions but can also help to change feed strategies and illustrate what is nutritionally available within the forage. This can help to meet the needs of a herd and manage overall input costs more accurately. Figure 3 illustrates how producers provide supplementation to their calves during backgrounding. Most producers are hand-feeding their calves daily (62%), 21% feed free-choice, and 16% hand-feed a few times a week. There were two producers who responded that they do not supplement with feed during the backgrounding phase. The last question of the survey was open-ended and asked respondents to specify the supplemental feedstuffs they provide calves. The most common responses were soybean hulls, dried distillers' grains, 50/50 soybean hulls and corn gluten feed, and whole cottonseed. All of these are common supplement feeds found in Alabama. With a majority of producers choosing to hand-feed their animals daily, management strategies such as working with intake limiters could be considered to help with key issues such as labor.

Backgrounding Pre-Sale Management and Marketing

As previously shown in Table 3, respondents who background their calves were also asked about other management strategies they practice prior to sale including vaccination (83%), castration (81%) and use of implants (37%). In comparison to respondents who do not background their calves, these practices were more commonly performed, although the percentage implanting calves was relatively low. While more than 90% of feedyards utilize implants, and they have been shown to be a cost-effective way to increase weight gain in calves (Beck et al., 2014), adoption of implants may be less in part due to awareness, lack of familiarity with their use, or expected marketing outcomes for calves (i.e. natural beef marketing programs where implants are not used). When marketing their calves after backgrounding, most producers sell their calves at a local livestock auction (Table 5). Direct market sales are the second-most frequent method of marketing calves after backgrounding. Producers also utilize local special sales (28%) like board sales or online auctions (9%). Almost 14% of producers stated that they retain ownership of their calves through the feedyard finishing phase.

Extension and Industry Educational Response

Results of this survey can be used to develop and Extension educational response towards enhancing weaning and backgrounding management application in Southeast U.S. beef cow-calf operations. Development of educational demonstration models may provide a stepwise approach to help producers make decisions regarding the adoption of weaning and backgrounding management practices. Cost-benefit tools may help producers weigh decisions regarding weaning management, and if backgrounding may be profitable within a given year. Additionally, this information can be used to create an on-farm checklist which enables producers to identify areas of improvement which may be needed to make steps towards practice adoption or improve current weaning and backgrounding strategies utilized on farm. Challenges such as lack of market predictability and marketing opportunities can be met with education focused on communication with stockyards prior to selling calves and full understanding of available premiums offered for backgrounded animals. Programmatic partnerships with industry professionals may help bring new or value-added information to beef cattle producers with the aim of increasing the use of various technologies or enhancing marketing opportunities for adopted practices.

Applications

The purpose of this survey was to determine the perceptions of weaning and post-weaning management strategies among state producers and the barriers they face in their operations. Results indicated that while many different management strategies are used, input costs and unpredictability of the market are common drivers of the decision to practice or not practice post-weaning management strategies. With this data, potential educational gaps for cow-calf producers have been identified. Extension educators in the Southeast U.S. region can use this information to create programming and resources centered around those needs to improve overall understanding and potential adoption related to calf management during weaning and post-weaning phases.

Acknowledgments

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Table 1. Ranking of challenges for Alabama beef cattle operations from most relevant to least relevant**.**

-	Rank (% of responses)								
Issues	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**
Input costs	88	71	24	4	2	0	0	2	1
Land availability	69	27	17	22	16	8	9	6	18
Market predictability	11	34	57	40	21	13	10	5	1
Marketing options	2	16	29	46	31	24	21	19	4
Sickness	4	9	11	19	49	54	29	14	3
Facilities	9	12	28	22	20	41	28	21	11
Labor	8	22	23	21	25	17	22	47	7
Stress	1	0	3	16	17	20	62	59	14
Wildlife	0	1	0	2	11	15	11	19	13

Figure 1. Marketing outcomes of Alabama beef calves post-weaning.

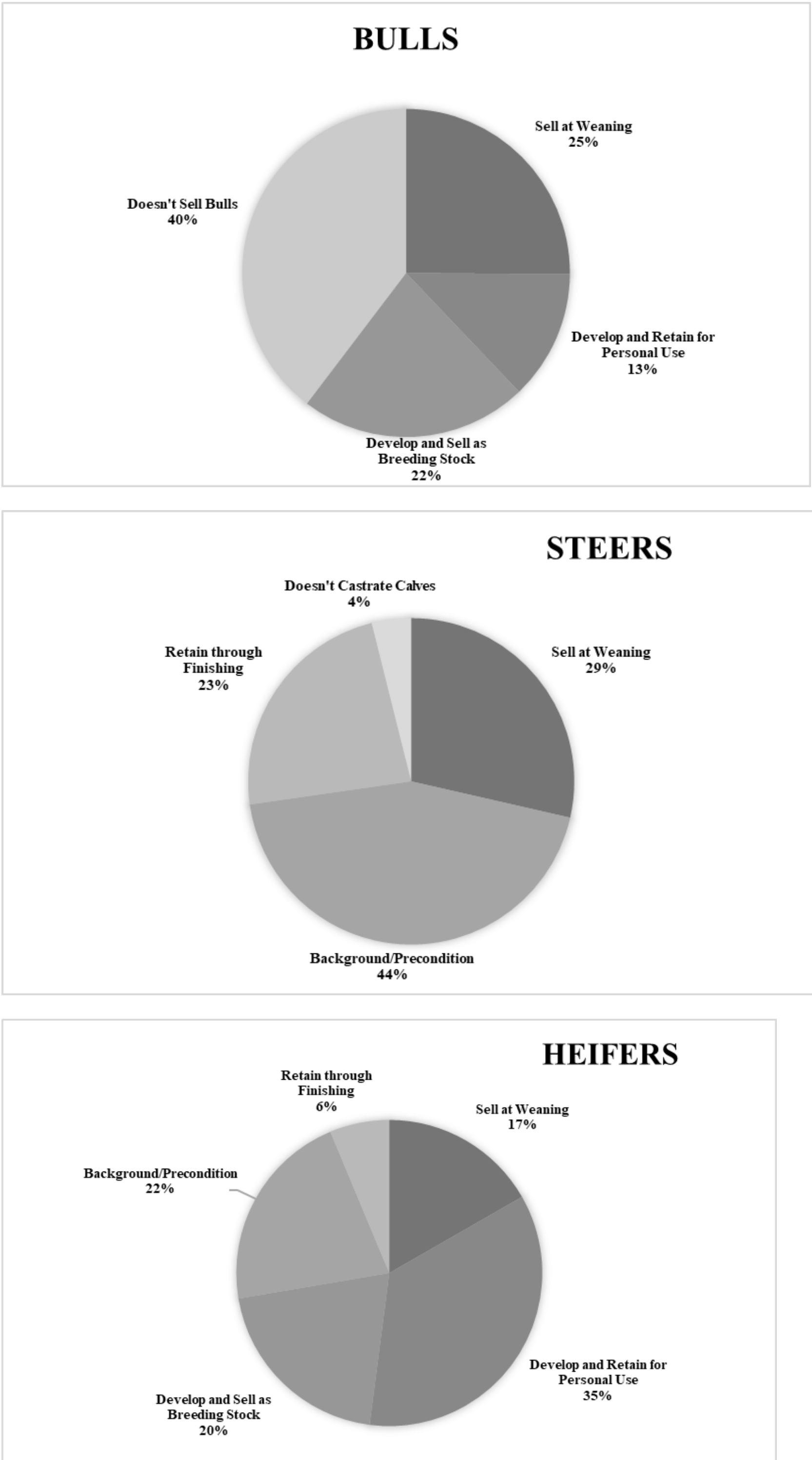

Table 2. Producer perceptions and reasoning behind not backgrounding calves in Alabama beef cattle operations.

Management reasoning	**Respondent percentage[1]**
Market variability	66.7%
Facilities	48.1%
Time commitment	44.4%
Land availability	40.7%
Production costs	33.3%
Labor	25.9%
Lack of knowledge	25.9%
Other	14.8%
Respondent count	**27**

[1]Respondents could select more than one answer.

Table 3. Management practices followed by producers prior to marketing as influenced by the choice to background calves.

		Divided by backgrounding	
Management method	**Overall method use**	**No[1]**	**Yes**
Vaccination	79.3%	59.3%	82.5%
Castration	78.8%	66.7%	80.7%
Implantation	34.2%	18.5%	36.7%

[1]No = producer does not practice backgrounding; Yes = producers backgrounds calves in all or most years.

Table 4. Forms of identification utilized by Alabama beef cattle operations.

Method of identification	Overall method use[1]
Plastic Ear Tag	95.2%
Tattoo	25.3%
Electronic Ear Tag	19.3%
Hot Brand	12.0%
Freeze Brand	10.2%
Metal Tag	10.2%
Ear Notches	7.8%
Other	1.2%
None	0%
Respondent count	**166**

[1]Respondents could select more than one answer.

Figure 2. Forms of grazing management used by Alabama beef cattle producers during the backgrounding phase**.**

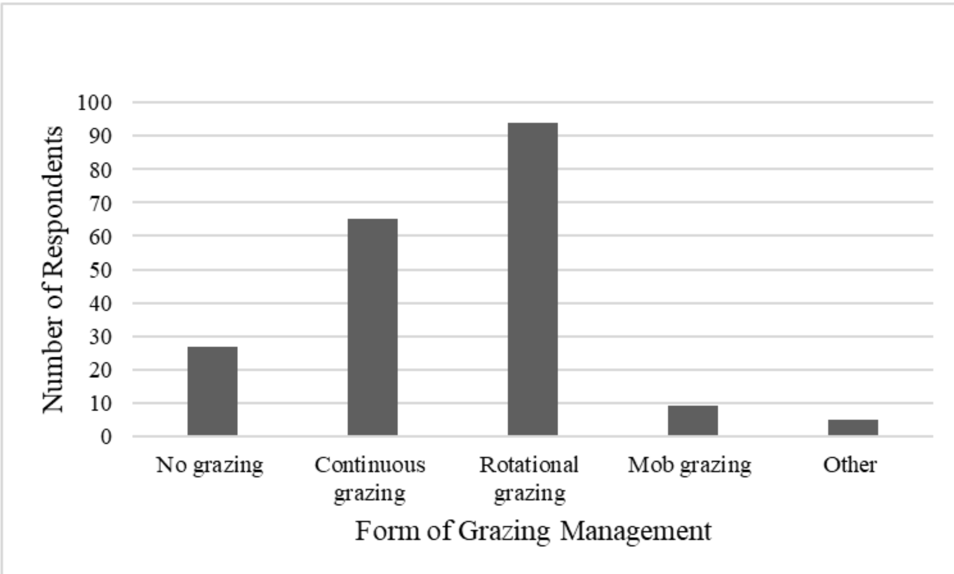

Figure 3. Forms of providing supplementation used by Alabama beef producers during the backgrounding phase.

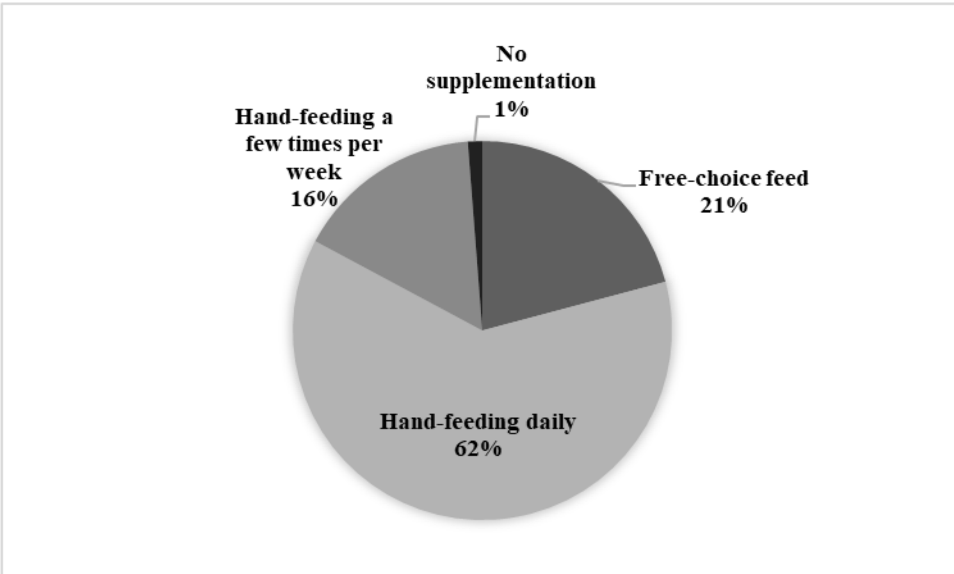

Table 5. Forms of marketing Alabama beef calves following a backgrounding period.

Form of marketing	Overall method use[1]
Local livestock auction	53.6%
Direct market sales	37.3%
Local special sale[2]	27.7%
Retain ownership[3]	13.9%
Online auction	9.0%
Other	7.2%
Respondent count	**166**

[1]Respondents could select more than one answer.
[2]Local special sale was described such as a board sale etc.
[3]Retain ownership through the feedyard phase

Chapter 3: Weaning management methods and effects on growth performance and health in southeastern beef calves

Introduction

Weaning is considered to be one of the most stressful time periods in the life of a beef calf (Wilson et al., 2017). Beef calves can be highly susceptible to illness and disease due to the stress of the weaning process. Stress invoked during weaning includes separation from the dam, processing, exposure to new environments, commingling with unfamiliar calves and long transportation events. All of these events are individual stressors on young animals, but these events compounded all in a short period of time can have even greater effects on health and performance of beef calves post weaning (Arthington et al., 2008; Taylor et al., 2010). Overall, performance of beef calves post weaning continues to be a major concern as issues such as bovine respiratory disease complex (BRDC) continue to have a large negative economic impact on the beef cattle industry (Babcock et al., 2009; Bhatt et al., 2021).

During weaning, beef calves often exhibit decreased feed intake, decreased average daily gain (ADG) and increased behavioral responses such as pacing and vocalization (Sayre et al., 2019). The stress associated with weaning reduce immune responses and leads to immunosuppression. Immunosuppressed calves exposed to respiratory viruses during commingling have a greater risk of developing BRDC-associated morbidity and mortality in other stages of production (Buhler et al., 2019). Vaccination during weaning is a common strategy among producers to reduce the incidence of BRDC morbidity and mortality (Step et al., 2008). However, a compromised immune system due to stress associated with weaning may not be able to respond as expected to vaccinations (Riggs et al., 2011). Evaluation of weaning management methods may result practices that can be implemented on farms to reduce stress and improve the transition of beef calves into the backgrounding period.

Traditional weaning, commonly referred to as abrupt weaning or total separation, is defined as complete separation of the calf from its dam at a single time (Wilson et al., 2017). The calf and dam are completely separated with no additional contact (Riggs et al., 2011). This allows the farmer to immediately sell, and ship weaned calves the same day, but usually results in greater stress and incidence of disease post-weaning (Haley et al., 2005; Wilson et al., 2017). Alternative weaning methods may help reduce stress of calves going into the next stage of production. These methods attempt to mitigate stress of weaning by gradually transitioning calves through dam separation rather than complete separation at a single time (Boland et al., 2008). Fenceline weaning is a practice where calves are removed from their dams and placed on opposite sides of a fence. This prevents calves from suckling but still allows them to have some form of contact with their dam (Price et al., 2003). Two-stage weaning, or sometimes referred to as nose-flap weaning, is a more recently developed method of weaning. This method uses a suckling device such as a nose-flap to cease suckling, allowing calves to learn independence while still at their dam's side (Taylor et al., 2019). Few studies have looked at these different weaning management strategies in Southeastern weaned beef calves. Studying weaning strategies provides a proactive approach to improve calf health in contrast to the reactionary approach practiced upon arrival at the feedyard following transport of highly stressed weaned beef calves. Therefore, the objective of this study was to evaluate the effects of different weaning methods in Southeastern beef calves on backgrounding growth performance [body weight (BW) gain] and health.

Materials and Methods

All procedures for the study were approved by the Auburn University Institutional Animal Care and Use Committee for the use of live vertebrate animals in experiments (IACUC 2021-3880).

Animals

A two-year study was conducted in 2021 and 2022 using 427 Angus × Simmental steer calves (year 1: n = 216, 297.4 ± 3.1 kg BW; year 2: n = 213, 291.1 ± 3.1 kg BW) from three Auburn University research farms (E.V Smith Research Center, Shorter, AL; Black Belt Research Center, Marion Junction, AL; Gulf Coast Research Center, Fairhope, AL). Prior to weaning at 3 to 4 months of age, all calves were vaccinated with Bar-Vac 7/Somnus® (Boehringer Ingelheim Vetmedica, Inc., St. Joseph, Missouri). At weaning (D0), calves were vaccinated with a single dose of a multivalent modified-live virus (MLV) respiratory vaccine (Pyramid® 5 + Presponse®- Boehringer Ingelheim Vetmedica, Inc., St. Joseph, Missouri) and dewormed with a pour-on dewormer (Eprinex® Pour- Boehringer Ingelheim Vetmedica, Inc., St. Joseph, Missouri) and then assigned to one of three weaning method groups. Assignment of treatments groups was such that each farm of origin had equal numbers of animals and average body weight was equal across treatment groups. Treatment groups were: 1) abrupt weaning (**AB**), 2) fenceline weaning (**FL**), or 3) nose-flap weaning (**NF**). Body weight (BW) was measured on all animals on D0 (at weaning), D14 (end of weaning), and D28 and D58 to assess the carryover effects following weaning into the backgrounding period. Body weights were also measured 24 hours following any transportation event. Blood samples were collected to determine acute phase responses surrounding the transportation event.

Fenceline calves remained at their farm of origin for the 14-d weaning period. After BW collection, calves allocated were out to pasture with a fenceline conjoining their dams' pasture to allow contact but having physical separation. Nose-flap weaned calves also remained at their farm of origin. During initial processing on D0, a QuietWean Nose-Flap (QuietWean, Saskatoon, Canada) was inserted into the nose of each calf to prevent suckling. Calves were then turned back out on pasture with their dams. Abruptly weaned calves were separated from their dams at a single time and the same day transported to a new farm for backgrounding (E.V. Smith Research Center). All calves were maintained on pasture of mixed warm-season perennials and 50:50 soyhull-corn gluten pellet feed for the weaning period to maintain consistency across all farms. For the AB and FL calves, feed was offered at free choice daily at up to 1% of average BW. For the NF group, feed was offered daily in pasture creep feeders to avoid competition with dams.

Transportation

On weaning day (D0) following vaccination and blood collection, steers in the AB group were loaded onto trailers and traveled to the E.V. Smith Research Center in Shorter, AL. At all three locations calves were loaded using a loading ramp and low stocking densities in each trailer were attempted to avoid any extra stress on animals. Regardless of farm of origin all steers traveled approximately 320 km or 3 hours that day. At 24 hours post travel, on D1 steers were reweighed to measure shrink recovery. On D14 steers in the FL and NF groups were loaded onto trailers and traveled to the E.V. Smith Research Center. These groups also traveled 320 km regardless of farm of origin. Following a 24 hr recovery period, the FL and NF steers were weighed.

Blood Collection

Blood samples were collected for analysis of serum concentrations of haptoglobin (HP) to compare the acute-phase response between weaning treatments. In year 1 samples were taken right before transportation and 24 hr following transportation. Based on year 1 results, in year 2 a subset of calves from each treatment group (n = 15) were selected to collect additional samples at more intervals: pre transportation, 24 hr following transportation, and again 3- and 7-days post transport. Blood samples were collected via jugular venipuncture. Samples were processed at the Auburn University School of Veterinary Medicine Sugg Laboratory (Auburn, AL). Blood was allowed to clot at room temperature, then centrifuged for 230 m at 1,200 × g to separate blood fractions. Serum was collected into cryovial tubes and frozen at -80°C for later analysis. Haptoglobin analysis of serum samples was conducted using a commercial ELISA kit (Bovine Haptoglobin ELISA Kit, ICL Inc., Portland, OR) at the West Texas A&M University Animal Health Laboratory (Canyon, TX).

Statistical Analysis

The experiment was a completely randomized design. Weaning treatment was considered the main effect and included 1) abrupt weaning, 2) fenceline weaning, and 3) nose-flap weaning. Continuous variables such as body weights (BW), average daily gain (ADG), and hematological parameters were analyzed using the GLIMMIX feature in SAS 9.4 (SAS Institute, Inc., Cary, NC). Individual animal was the experimental unit for all variables. In addition to within treatment replication, the project was replicated in time over two years. A Fischer-protected test of least squared differences was used for mean separation and alpha was set at 0.05 to determine significance.

Results and Discussion

There was no difference in body weights from each treatment group at the initiation of the weaning period on D0 in both years of the study ($P = 0.80$). Initial body weights and weights at each time period over the study for the calves in the different weaning treatments are depicted in Figure 4. At the end of the weaning period on D14, FL calves had the highest average body weight at 303.4 kg ($P = 0.03$) with calves in the AB group having the lowest average weight at 294.2 kg. Two weeks following weaning at D28, there was no significant difference in body weights among calves across weaning methods ($P = 0.74$). However, by D58, FL calves had the greatest gain ($P = 0.004$) in the following 30 days, gaining 35.0 kg compared to NF and AB calves (28.4 kg and 27.8 kg respectively). In both years of the study, FL calves had the greatest average daily gain (ADG) during the 14-d weaning period at 1.1 kg/d ($P < 0.0001$; Figure 5). Calves that were abruptly weaned had the lowest ADG losing 0.15 kg/d during the 14-d weaning period. There was a treatment × year effect ($P = 0.0008$) for ADG in the weaning period for NF and AB weaning methods. In year 1, NF calves had an ADG of 0.79 kg/d and in year 2 had an ADG of 0.35 kg/d ($P = 0.02$). For the AB calves, there was an ADG of 0.40 kg/d in year 1 whereas in year 2 calves in the AB group had the lowest ADG across the study losing 0.70 kg/d ($P < 0.0001$). In year 1, calves had a significantly greater ($P < 0.0001$) gain across all treatments than calves in year 2, with year 1 calves gaining 7.7 kg more during the weaning period than year 2 calves (Figure 6). Weather differences between Year 1 and Year 2 likely impacted gains during the 14-d weaning period. The average temperature during the weaning period in Year 1 was 30.0ºC compared to 34.4 ºC in Year 2. High temperatures in combination with high humidity has been shown to negatively impact cattle performance (Boyles, 2008). Overall, FL calves had the highest ADG during the weaning period with the largest difference between years being seen in the AB weaned group. This advantage on heavier weights from FL weaned group could lead to larger profits for producers who sell calves at weaning or shortly afterwards. In the Southeast, calves are typically sold at weaning on a kg of BW basis. While a premium may not always be received based upon the health improvements producers make in a good weaning management, calves that gain weight during the weaning process result in better net financial returns for producers (Hilton, 2015). The price paid is not under the control of the producer, but the pounds of calf sold is primarily under the control of the producer and is important when looking at the small margin of returns that cow-calf producers are often facing (Mathews and McBride, 2011; Hilton, 2015).

Table 6 illustrates the weight loss 24 hr following each transportation event for each treatment group. The FL calves had the greatest weight loss following transport event at 19.8 kg with the NF and AB steers losing 16.3 kg and 11.4 kg respectively ($P < 0.0001$). While the FL group had the highest shrinkage from transport, this effect was not sustained into the backgrounding phase. Figure 4 provides information on performance by D58 of study. The FL calves had the greatest gain and the highest overall ADG. Fenceline weaning in this study had similar performance to other studies (Price et al., 2003) with higher gains during the weaning period. This is attributed in part to animals being able to cope with different stressors during weaning better than other management methods. Weaning with devices such as nose-flaps has been noted to have similar performance in the same way as fenceline weaning by breaking up the stress of weaning but allowing calves to remain with their dam for an adaptation period (Riggs et al., 2011). Research continues to be divided on the success of this weaning method (Haley et al., 2005; Freeman et al., 2016). The ADG for NF calves was greater than AB calves weaned group during the 2-week weaning period. This does not agree with earlier studies such as Haley et al.

(2005) where it was reported that during the period of weaning, calves experienced lower ADG but greater ADG in the 7 days following separation. Freeman et al. (2016) found similar results to these with lower ADG during the weaning period and 42 days post weaning. While some studies such as Lambertz et al. (2015) observed issues with the nose-flap such as nasal abrasions, this was not something observed in this study regardless of the length (14 days) the flaps were left in. It was observed in this study situations in which calves were still able to suckle with the flap still in. This was not a common occurrence but this could still bring into question how affective the flaps are on fully breaking the maternal bond. There continues to be questions on length of time needed for the nose-flap devices to be effective. Other studies have shown possible compensatory growth following abrupt weaning (Taylor et al., 2011) While this might have been the case in the gain following D14 with AB calves, the fenceline calves were able to recover much faster following transport, resulting in the overall greatest ADG across the entire study.

In year 1, AB weaned calves had greater serum levels of haptoglobin (0.084 mg/mL: P<0.0001; Figure 7) than both the FL and NF treatment groups (0.023 mg/mL; 0.020 mg/mL) following transportation. Two weeks following transportation, serum haptoglobin (HP) levels were not significantly different among treatment groups. Haptoglobin and other acute phase proteins are good indicators of stress in cattle (Oui et al., 2007). Because of its high sensitivity and response to oxidative stress in the body, results from several studies demonstrated that plasma concentrations of HP are negatively correlated with performance in healthy cattle (Cooke and Arthington, 2013). In a study conducted by Wottlin et al. (2020) a significant decrease in dry matter intake and weight gain was observed in cattle 28 days following different magnitudes of HP responses resulting from experimental challenge with *Mannheimia haemolytica*. In this study, steers with the highest HP response after challenge had a lower final body weight and tended to have a lower dry matter intake (Wottlin et al., 2020). Growth performance and dry matter intake are critical assessments factors of animal health. Overly stressed animals do not gain weight successfully (Taylor et al., 2011). Our results suggest that abrupt weaning results in a greater level of stress and pro-inflammatory response in beef steers compared with FL and NF weaning methods. The effects of greater stress and pro-inflammatory responses are reflected in suboptimal performance (lower weight gains) in abruptly weaned calves during the initial phase of the backgrounding period. Additionally, we speculate that in cases of conventional marketing conditions of the Southeast, where the majority of abruptly weaned calves are marketed through auction barns, grater stress and pro-inflammatory responses could increase the risk of bovine respiratory disease complex (BRDC) in these animals.

Summary and Conclusions

The results from this study demonstrate that weaning management strategies may influence calf growth performance and the transition into the post-weaning period. It has been well recognized that weaning is a stressful event in a calf's life, and research continues to investigate the effects that weaning management may have on calf performance later in life. Calves that are born in the Southeast are often at a disadvantage following weaning because of the long journey they have to the final stage of production at the feedyard (Babcock et al., 2009). All of these predisposing factors often lead them to be more susceptible to disease such as BRDC. Management pre- and post-weaning can have a large impact on the performance and health of these animals.

Weaning methods vary greatly among cow-calf producers and methods that may work well for one producer do not always yield the same results for others. Therefore, selection of weaning strategies for cow-calf production systems should be based on management practices and resources available in each individual case. Additional research on nose-flap design and length of wear differences could provide further insight on decision-making to maximize their potential benefits. Fenceline weaning continues to provide a suitable alternative to abrupt weaning in cow-calf production systems. Based on the result of this study, fenceline could reduce stress and pro-inflammatory responses as well as improve performance and well-being of beef calves during the post-weaning and backgrounding period. This weaning management strategy could in turn, increase the economic value of the calf and investment return leading to greater profits for the producer.

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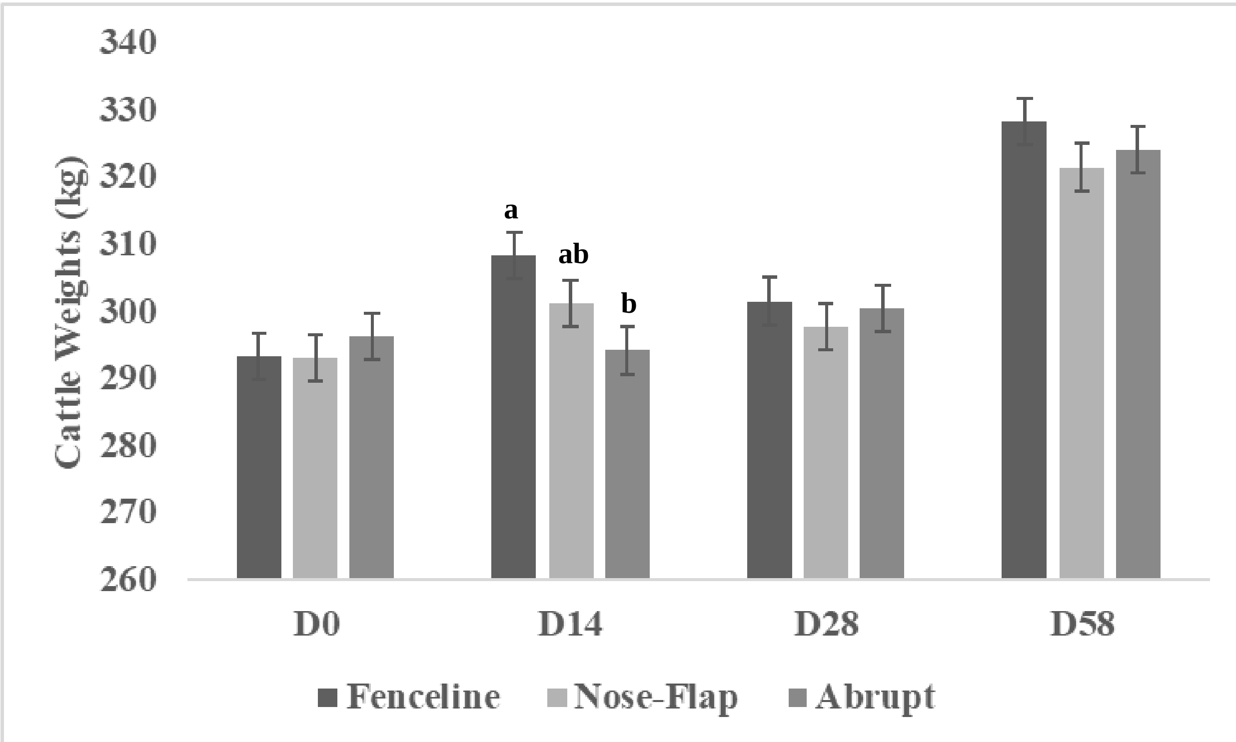
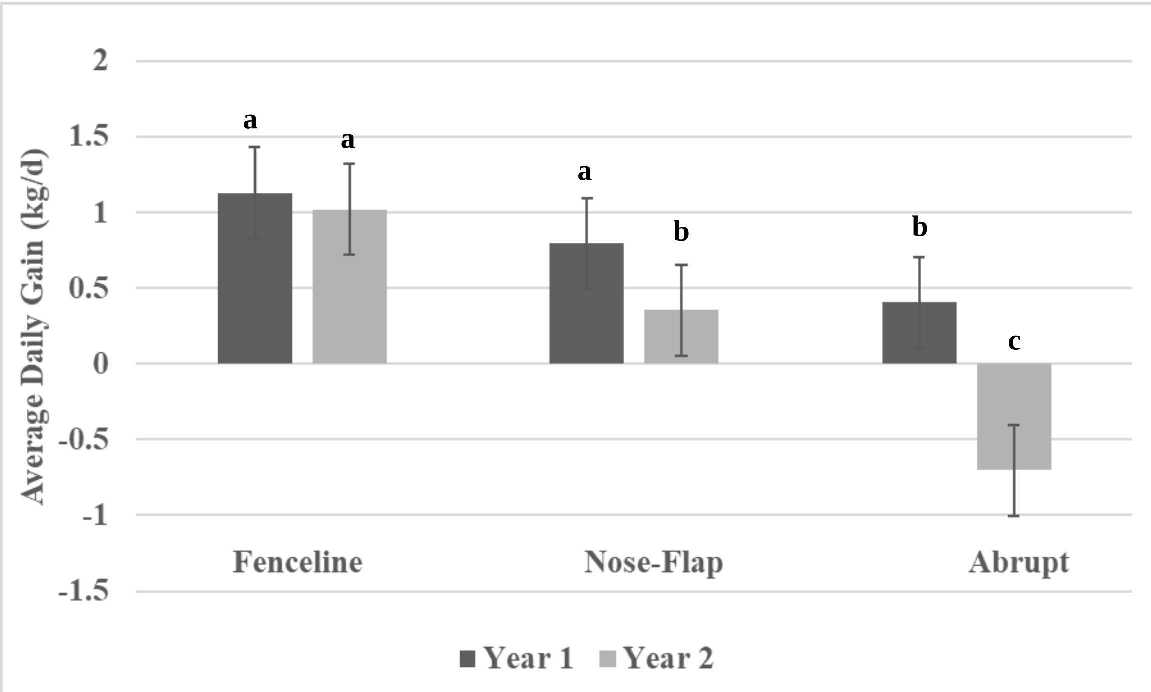
Figure 4. Mean body weight (kg) of calves at intitiation of study, the 2-week weaning period and 30 days into the backgrounding period.



[ab] Denotes differences in cattle body weight by weaning treatment at each time point ($P < 0.05$).
D0- Initiation of study at weaning ($P = 0.80$).
D14- End of weaning period ($P = 0.02$).
D28- Beginning of backgrounding period ($P = 0.74$).
D58- Mid point of backgrounding period ($P = 0.42$).

Figure 5. Mean average daily gain (kg/d) of calves during the 2-week weaning period compared across weaning treatments and years.



[abc] Denotes differences in ADG across weaning treatment and years ($P < 0.05$).

Figure 6. Differences in cattle body weight gain (kg; $P < 0.0001$) compared between the two years of study.

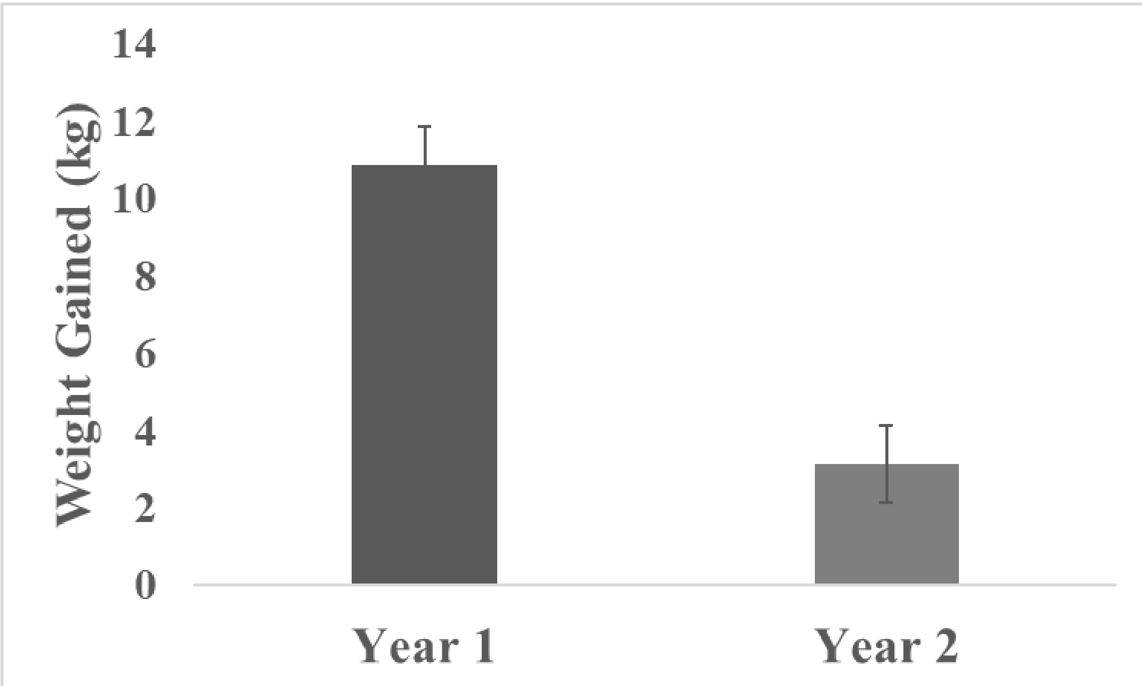


Table 6. Calf body weight and percentage of body weight shrink loss following transport from farm of origin to Shorter, AL.

	Weaning Treatments[1]				
Body Weight, kg	FL	NF	AB	SEM	*P*
Pre-Transport[2]	324.1	342.3	341.6	--	--
24 h Rest[3]	302.3	315.9	313.7	--	--
	Weaning Treatments				
Shrink Loss	FL	NF	AB	SEM	*P*
%, 24 h Rest	7.1[a]	7.2[a]	4.4[b]	0.3	<0.0001
Weight, kg	19.8[c]	16.3[d]	11.4[e]	1.1	<0.0001

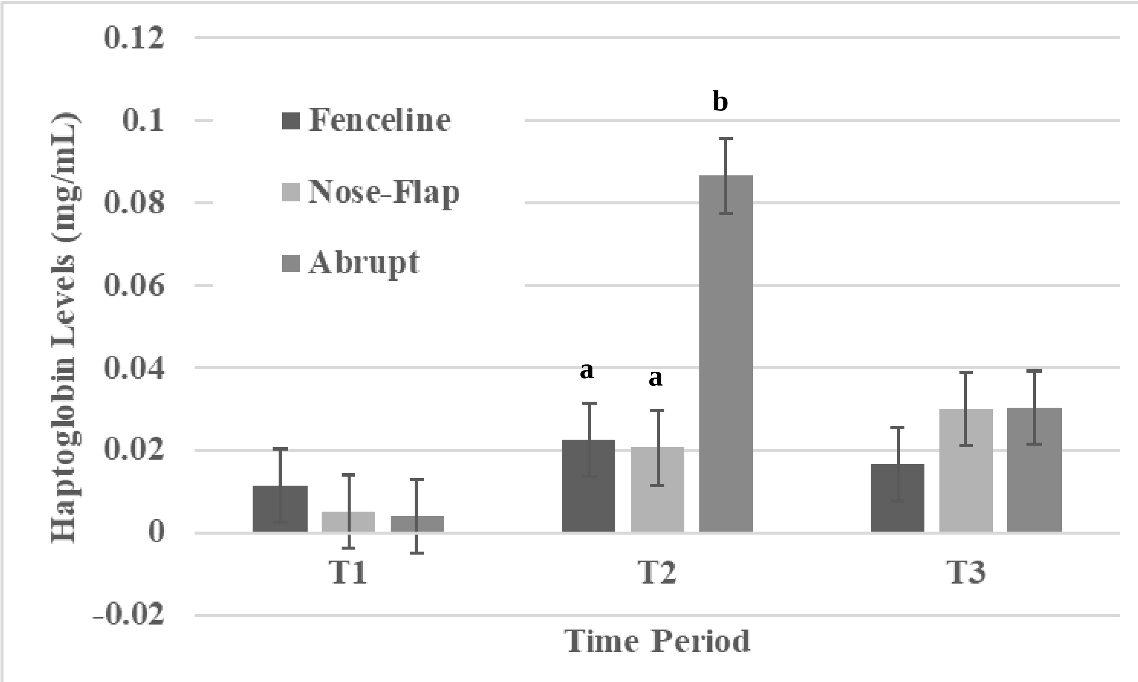
[abcde] Means within the same row with different superscripts are significantly different ($P < 0.05$)

[1]Weaning Treatments are defined as FL= Fenceline Weaning; NF = Nose-flap weaning; AB = Abrupt Weaning

[2]Pre-Transport observations are those taken immediately before calves were loaded for transportation to Shorter, AL.

[3]24 h Rest observations are those taken after animals were allowed to rest with access to hay and water for 24 h after arrival.

Figure 7. Haptoglobin levels surrounding transportation events compared across weaning treatments.



[abc] Denotes differences in haptoglobin present across weaning treatment and years ($P < 0.05$).
T1 = Immediately before transportation event.
T2 = 24 hr post transportation event.
T3 = 14-days post transportation event.

Chapter 4: Extended effects of post weaning management in southeastern beef calves

Introduction

The United States beef industry can be divided into three major segments: the cow-calf, backgrounder (stocker), and the finishing/feedyard sectors (Field et al., 2016; Drouillard, 2018). Diversity in management strategies during each respective phase of production is common in operations across the industry and can influence a calf's performance and economic viability throughout its life (Hersom et al., 2003; Lancaster et al., 2014; Cox-O'Neill et al., 2017). Once calves are weaned, they begin the transition into the next phase of production. This transition adds a series of different stressors that could lead to disease, such as long transportation, events and being commingled with animals of different origin (Wilson et al., 2017). These stressors can cause immunosuppression, that subsequently can result in higher morbidity and mortality associated with the bovine respiratory disease complex (BRDC) and other diseases in the remaining stages of production (Buhler et al., 2019). The impact of BRDC on the United States beef industry is high, resulting in annual losses of almost one billion dollars (Caswell, 2014; Brooks et al., 2017; Theurer et al., 2021). The concept of the backgrounding sector was developed as a pre-feedyard arrival practice to reduce mortality and morbidity in the feedyard by strengthening animal immunity and increasing body weight (Duff and Gaylean, 2007; White and Larson, 2009). Overall impacts of different components of backgrounding management such as diet and length of time have been evaluated (Lancaster et al., 2014) but very few studies have focused on systems approaches, especially those modeling production system environments used in the Southeast U.S.

In the Southeast U.S., beef cow-calf systems are the predominant operations in the region. For many of these producers, traditionally, the mature cow herd is the focus of production and the risk associated with feeding cattle is too great prompting many of them to market their calves at weaning (Pope et al., 2011; McBride and Mathews, 2011). Cattle born and raised in the Southeast U.S. are often at a disadvantage from a disease susceptibility standpoint because 1) most cattle are fed in the Great Plains U.S. region and consequently calves have to be transported for long periods. 2) The journey to the feedyard post weaning is characterized by stops at auction barns and stocker farms where commingling and exposure to infectious pathogens is common (Babcock et al., 2009). However, producers in the Southeast U.S. have an advantage to facilitate almost year-round grazing for cattle, utilizing both warm-season and cool-season forage systems (Ball et al., 2015). These forages can be used to develop nutritional management systems for backgrounding calves post-weaning in the region. In fall calving season, where animals are weaned and subsequently backgrounded on warm-season grass systems, perennial forages such as bermudagrass (*Cynodon dactylon*) may not be able to sustain profitable gains for growing calves due to lower quality and decreased digestibility during the mid- to late growing season (Beck et al., 2016). Warm-season annuals such as crabgrass (*Digitaria sanguinalis*) have been shown to be highly productive forages that can adequately meet growing cattle nutritional requirements and withstand intense stocking rates (Ball et al., 2015). Drylot backgrounding strategies using stored forages such as hay or baleage may also be options for cow-calf operations as climatic conditions vary, decreasing sole dependence on pasture conditions (McCormick, 2013). These methods allow for producers to harvest forages at peak nutritive value and use them in later seasons to fill the nutritive gap in the summer months and support adequate gains for growing beef calves.

Significant research efforts have focused on management practices in the weaning and post-weaning phase that can help to reduce health risks and improve performance in calves.

However, this work has been largely focused during this period in Midwestern operations. (Duff and Gaylean, 2007; Lancaster et al., 2014). Weaning and post-weaning management practices have the potential to influence animal performance and success in the feedyard. The objective of this study was to evaluate the effects of weaning and post-weaning management practices and potential carryover effects on calf immune system viability and calf performance through the feedyard finishing phase in Southeast U.S. beef calves.

Materials and Methods

All procedures for the study were approved by the Auburn University Institutional Animal Care and Use Committee for the use of live vertebrate animals in experiments (IACUC 2021-3880).

Animals and Weaning Management

A two-year study was conducted in 2021 and 2022 using 427 Angus × Simmental steer calves (year 1: n = 216, 297.4 ± 3.1 kg BW; year 2: n = 213, 291.1 ± 3.1 kg BW) from three Auburn University research farms (E.V Smith Research Center, Shorter, AL; Black Belt Research Center, Marion Junction, AL; Gulf Coast Research Center, Fairhope, AL). Prior to weaning at 3 to 4 months of age all calves were vaccinated with Bar-Vac 7/Somnus® (Boehringer Ingelheim Vetmedica, Inc., St. Joseph, Missouri). At weaning (D0) calves were vaccinated with a single dose of a multivalent modified-live virus (MLV) respiratory vaccine (Pyramid® 5 + Presponse®- Boehringer Ingelheim Vetmedica, Inc., St. Joseph, Missouri) and dewormed with a pour-on dewormer (Eprinex Pour-On, Boehringer Ingelheim Vetmedica, Inc., St. Joseph, Missouri) and then assigned to one of three weaning method groups. Assignment of treatments groups was such that each farm of origin had equal numbers of animals and average body weight was equal across treatment groups. Treatment groups were: 1) abrupt weaning (AB), 2) fenceline weaning (FL), or 3) nose-flap weaning (NF). Fenceline calves remained at their farm of origin for the weaning period and were housed on pasture with a fenceline conjoining their dams' pasture during the weaning period. This allowed contact among dams and calves but provided physical separation to allow for weaning to occur. Nose-flap weaned calves also remained at their farm of origin. During animal processing for vaccinations, a QuietWean Nose-Flap (QuietWean, Saskatoon, Canada) was inserted into the nose to prevent suckling. This group was then allocated back to pasture with their dams. Abruptly weaned calves were not given a transition period to promote independence from their dams. At weaning, AB calves were transported to E.V. Smith Research Center to simulate abrupt separation and movement from home environment. All calves were maintained on pasture and 50:50 soyhull-corn gluten pellet feed for the weaning period to maintain consistency across all farms. Following the end of the 14 day weaning period calves from the FL and NF groups were also transported the E.V. Smith Research Center. All transportation events had a target of 3 hours travel time regardless of farm of origin.

Backgrounding and Animal Management

On day 21 of study following a 7-d acclimation period post-arrival at the backgrounding facility, calves were weighed and assigned according to weight, previous weaning management treatment and farm of origin into their respective pen groups. Pens were assigned into three dietary treatments (n = 9 pens per treatment). Backgrounding diets were: 1) drylot with ad libitum cool-season annual baleage [annual ryegrass (*Lolium multiflorum*), crimson clover (*Trifolium incarnatum*), and oats (*Avena sativa*)] and 1% of body weight (BW) dried distillers grains with solubles (DDGS) fed daily (**BD**), 2) drylot with ad libitum bermudagrass hay and 1

% of BW of DDGS fed daily (**HD**), or 3) grazing a warm-season annual mixture of crabgrass (*Digitaria sanguinalis*), pearl millet (*Pennisetum glaucum*), and forage soybean (*Glycine max*) and 1% of BW of DDGS fed daily (**GD**). These diets were selected to reflect common backgrounding management systems and feeding practices used by beef cattle producers in the Southeast U.S. region (Table 7). Supplementation amounts of DDGS were adjusted to achieve 1% of BW after cattle weighing events throughout the backgrounding period. In drylot diets, conserved forage was fed in open-style metal hay rings, and for all diets DDGS were fed in concrete bunks daily. Body weights were measured on D21, initiation of the backgrounding period on D28, at the midway point on D58, at the end of the backgrounding period on D88 and then prior to leaving for the feedyard on D106.

Animal Health Management During Backgrounding

At initiation of the backgrounding period on D28 steers received a Bar-Vac 7/Somnus® booster vaccination and were implanted with a growth promoting hormone implant (SYNOVEX-S, Zoetis Animal Health, Parsippany-Troy Hills, NJ). On D88 at the end of the backgrounding period, steers were re-vaccinated with Pyramid® 5, given a corresponding state Radio Frequency ID Tag (RFID) and a killed virus autogenous vaccine (Newport Laboratories, Inc. Worthington, MN). During the study, animal health status was checked daily.

Forage Management

For the grazing diet, a warm-season annual mixture of crabgrass, peal millet, and forage soybean was planted into a prepared seedbed at a planting rate of 4.5 kg/ha, 16.8 kg/ha, and 28.0 kg/ha respectively. This seeding rate used was based on Extension recommendations for warm-season annual forages in Alabama (Dillard et al., 2019). Pastures were planted on April 26th and

May 17th in 2021 and 2022, respectively. Following planting, pastures were fertilized with 56 kg N/ha, and P and K was applied according to Auburn University soil test recommendations. Pasture for grazing treatments were 2.4 ha each and subdivided into 0.8 ha paddocks using temporary electric fencing. When grazing was initiated on paddocks, average forage height was 35.2 cm and pastures managed on a 7-d rotation during the backgrounding period. Forage samples were collected weekly to a 2 cm stubble height for determination of forage mass and nutritive value characteristics: crude protein (CP), neutral detergent fiber (NDF), acid detergent fiber (ADF), and total digestible nutrients (TDN). In conserved forage diets, core samples were collected using a forage probe bi-weekly according to the methods of Mullenix and Johnson (2018) and analyzed for nutritive value. Samples were sent to the Elk River Forage Lab (Elk River, MN) for NIR analysis (NFTA, 2002). All conserved forage was harvested from a single lot, and sampling points were selected across the feeding period to characterize any within-lot variation in forage. Baleage bales were replaced every 3-days to avoid spoilage.

Serum neutralization assays

Blood samples were collected at weaning prior to vaccination, D28, at D88 before re-vaccination and then three weeks following the autogenous vaccine at D106. Serum samples were taken for evaluation of neutralizing antibodies against BVDV 1a, BVDV 2a, and BHV-1. Samples for blood serum were collected via jugular venipuncture. Samples were then processed at the Auburn University School of Veterinary Medicine Sugg Laboratory (Auburn, AL). Blood was allowed to clot at room temperature, then centrifuged for 230 m at 1,200 × g to separate blood fractions. Serum was collected into cryovial tubes and frozen at -80 °C for later analysis. After processing, samples were sent to the Kansas State Veterinary Diagnostic Laboratory in Manhattan, KS to evaluate BHV-1, BVDV 1a and BVDV 2a serum neutralizing antibody titers as previously described (Chamorro et al., 2016). The BVDV 1a cytopathic Singer strain, BVDV 2a cytopathic 125 c strain, and BHV-1 Colorado Strain were used in virus neutralization assays. Briefly, Serum samples were thawed, and heat inactivated in a water bath at 55°C for 30 minutes, then serial 2-fold dilutions (1:10 to 1:1,000) were made in 96-microwell flat-bottom plates, then 500 µL of 100 TCID50 BHV-1, BVDV 1, and BVDV 2, respectively, suspended in minimum essential medium were added to all wells. For each dilution, 3 microwells were inoculated with equal volumes of virus culture media. Following incubation at 37°C in 5% CO_2 for 1 hour, MBDK cell cultures were inoculated with minimum essential medium that included 7% bovine serum and an antibiotic/antimycotic solution containing streptomycin, penicillin, and amphotericin B. The plates were incubated for 2 weeks and monitored daily for the presence of cytopathic effect. Antibody titers were reported as the inverse of the lowest dilution of serum required to inhibit all cytopathic effect and were Log_2 transformed for statistical analysis.

Transportation and Feedyard Management

Following D88 of the study, calves remained on their respective backgrounding diets until they were transported to the Hy-Plains Feedyard in Montezuma, Kansas to be fed until harvest. Prior to shipment, pens were sorted into groups based on animal size and predicted number of days needed on feed, where they would remain in at the feedyard for the remainder of the study. These groups were based on size (large, medium and small) and grouped according to potential arrangement in the feedyard. Each feedyard group had equal number of treatments and traveled to the feedyard in these groups. Calves were weighed three days prior to shipment. On the day of shipment each year, calves were loaded onto semi-trucks beginning at 1400 h and transported approximately 1700 km directly to the feedyard without being unloaded during transport.

On arrival at the feedyard, calves were unloaded and placed in a holding pen with access to hay and water. At the time of unloading, calves were visually appraised for any signs of lameness, sickness, or distress by researchers and feedyard staff. After 24 h rest, calves were weighed and processed. Feedyard processing included calves being tagged with a feedyard tag and then dewormed with an oral drench oxfendazole (Synanthic, Boehringer Ingelheim Vetmedica, Inc., St. Joseph, Missouri), and injectable ivermectin (Ivermax, Aspen Veterinary Resources, Bimeda, Inc., Cambridge, Canada), vaccinated for BHV-1, BVDV 1 and BVDV 2 (Pyramid® 3, Boehringer Ingelheim Vetmedica, Inc., St. Joseph, Missouri), and implanted with a growth promoting hormone implant (Component TE-IS with Tylan, Elanco Animal Health, Greenfield, Indiana).

Animals were then moved to their respective feeding pen for the duration of the finishing period. Calves were provided a step-up diet during the first 28 d in the feedyard from hay to a corn-based ration. Calves were started on a starter ration that was high in fiber and gradually moved up to a finishing ration that consisted of steam-flaked corn, DDGS with solubles, and alfalfa (*Medicago sativa*) hay. The diet also included a mineral supplement, tylosin phosphate (Tylan 100, Elanco Animal Health, Greenfield, Indiana), and monensin (Rumensin, Elanco Animal Health, Greenfield, Indiana). In the final month of feeding, ractopamine hydrochloride (Optaflexx, Elanco Animal Health, Greenfield, Indiana) was also included in the diet.

Steers were monitored daily for health events by feedyard staff. Any treatment for suspected BRDC related illness was recorded and analyzed for differences between treatment groups. Morbidity and mortality during the feedyard phase were calculated based on the number of treatments received by calves, and the total death loss by backgrounding treatment. To measure gain during this phase, steers were weighed at approximately 35 d and 100 d post arrival to the feedyard, and average daily gains were calculated for each period. To minimize stress on the cattle and facility limitations, final weights were not individually gathered. Each group was weighed prior to being transported to the processing facility and estimated final weight was then predicted using the hot carcass weight (HCW) and the final group weight.

Cattle Harvest

The number of days on feed was determined by the average weight of the group. The large group was on feed 161 days, while the medium and small groups were on feed for 196 and 225 days, respectively. At harvest, calves were transported to a commercial beef processing facility and harvested in their feedyard groups. At the time of harvest calves were scanned in the facility by their RFID and were visually checked with their feedyard eartags. Prior to chilling, HCW were collected on each animal. After being chilled for approximately 36 h, carcasses were processed. Carcasses were ribbed between the 12th and 13th rib. Ribeye area (REA), backfat thickness, marbling score, calculated yield grade (CYG), USDA Yield Grade, and USDA Quality Grade were recorded by the plant and USDA-AMS personnel for each animal.

Statistical Analysis

This experiment is a completely randomized design with a 3×3 factorial arrangement of treatments. Fixed effects include 1) weaning method, 2) backgrounding diet strategy, and their interaction. Pen during the backgrounding phase was the experimental unit for all variables. Continuous variables were analyzed using GLIMMIX feature in SAS 9.4 (SAS Institute, Inc., Cary, NC). These variables included body weight (BW), average daily gain (ADG), hot carcass weight (HCW), *longissimus dorsi* cross sectional area (REA), marbling score (MARB), backfat thickness (BF), calculated USDA Yield Grade (CYG), and serum neutralizing antibody titer results. The natural logarithm of titer levels for IBR, BVDV 1a and BVDV 2a were analyzed as the response variable. Binomial data were analyzed similarly using GLIMMIX feature of SAS 9.4 with data being coded 1 = positive or 0 = negative. The binomial variables included percentage of carcasses that reached USDA Prime or Choice and death loss in the feedyard. For the categorical variables of number of medical treatments in the feedyard, the FREQ procedure of SAS 9.4 was used. For each variable, weaning method by backgrounding diet strategy interactions were analyzed. If there was no significant interaction, then weaning method or backgrounding diet strategy were reported. A Fischer-Protected test of east squared differences was used for mean separation and alpha was set at 0.05 to determine significance.

Results and Discussion

Backgrounding Phase

There were no weaning × backgrounding treatment interactions ($P \geq 0.7$) or main effect differences in body weight during the backgrounding period. Body weights at the beginning of the acclimation period on D21 of study and then body weights at each time period over the backgrounding phase for the calves in each different weaning and backgrounding treatment are depicted in Table 8. Constant growth over the backgrounding period was observed across all treatments and weigh days. In the first 30 days of the backgrounding period (Figures 8 and 9), both weaning treatment ($P = 0.02$) and diet ($P < 0.0001$) had a significant effect on ADG with an interaction of weaning by backgrounding ($P = 0.001$). Calves that were abruptly weaned and on the HD diet had the highest ADG at 1.1 kg/d. However, on average, fenceline-weaned calves had the greatest ADG at 0.89 kg/d when compared across weaning treatments in the first 30 days as shown in Figure 8. By the end of the second 30 days in the backgrounding period, this effect was no longer observed ($P = 0.82$). When comparing across the backgrounding diets in the first 30 days of backgrounding, calves in the HD group had the greatest ADG ($P < 0.0001$) at 1.0 kg/d compared to calves on BD and GD systems at 0.75 kg/d and 0.72 kg/d respectively. In the second half of the backgrounding period, the inverse response in ADG is depicted in Figure 9. In the second 30 days of the backgrounding period, calves in the HD had the lowest ADG ($P < 0.0001$) at 0.31 kg/d compared to calves in the BD and GD groups at 0.74 kg/d and 0.77 kg/d respectively. Across the entire 60 d backgrounding period, there was a significant difference ($P = 0.002$; Figure 10) in ADG across diets. On average calves in the BD group had an ADG at 0.75 kg/d, GD calves had an ADG at 0.74 kg/d and HD calves having an ADG at 0.66 kg/d.

Most backgrounding operations have a goal of reaching ADG of 0.68 kg/d or greater (Ball et al., 2015). When ADG in the first 30 days, all three weaning methods surpassed this goal, with FL-weaned calves having the greatest ADG. Alternative weaning methods such as FL weaning have been observed to increase calf performance after weaning compared to traditional weaning methods (Boland et al., 2008). It is important to note that this marked D 58 total from the time of weaning (14-d weaning period + 7 days acclimation + 30 days of backgrounding). Depending on the length of weaning and backgrounding period, producers have the opportunity to maximize on management decisions that work best for their operation.

In this study, all diets exceeded the ADG goal of 0.68 kg/d in the first 30 days of the backgrounding period. The GD and BD diets also met or surpassed this goal in the second 30 days as well, while the HD diet did not meet it. For the HD diet, the overall average was close at 0.66 kg/d but this is largely in part to the high ADG in the first 30 days. All three diets could be considered when selecting diets for Southeastern backgrounding operations. Because of higher input costs and a shorter grazing season, warm-season annual pastures are often overlooked (Ball et al., 2015). However, for short-term use as in backgrounding systems, increased in nutritive value and high yield capacity make these forages an attractive option for beef cattle operations (Tracey et al., 2010; Harmon et al., 2019). Drylot feeding systems may provide an option for backgrounding where there are space limitations for grazed forage resources. The addition of feed supplementation to these diets is common in order to achieve the elevated rates of gain often seen in backgrounding systems (Drouillard et al., 1999). It has been shown that DDGS are a good source of protein and energy in growing cattle (Wahrmund et al., 2011) and represent a relatively accessible feedstuff in the Southeast for cattle producers. Research has reported that supplementation of DDGS resulted in increase ADG compared to non-supplemented cattle (Gadberry et al., 2010; Beck et al., 2014). Producers can further adjust rates of supplementation to more closely achieve gain targets, which may be a strategy to consider in the second 30 d of backgrounding based on ADG responses observed in this study. Additionally, differences observed in the first 30 days of the backgrounding period between the HD diet and the BD and GD diets could have been due to the lack of adaptation to high-moisture forages. Similar effects were observed by Martin et al. (2015) when comparing bermudagrass hay, bermudagrass baleage and rye-ryegrass baleage. This could signify the importance of adaptation periods for animals when introducing ensilaged forages.

Virus neutralization titers

Data for the serum neutralizing antibody titers for BHV-1, BVDV 1a, and BVDV 2a during the weaning and backgrounding phases are presented in Figures 11, 12, 13, 14, 15, and 16 respectively. There was no weaning × backgrounding interaction ($P \geq 0.2$) for IBR serum neutralizing antibody titers (Figures 11 and 12); however, a significantly lower ($P = 0.004$) mean log2 serum BHV-1 antibody titer was observed in calves on the HD diet on D 106 compared with mean BHV-1 titers of BD and GD calves (Figure 12).

Figures 13 and 14 depict mean Log2 BVDV 1a serum neutralizing antibody titers. There was no weaning × backgrounding interaction ($P \geq 0.1$) observed. However, a main treatment effect was observed at D 88 and D 106 ($P = 0.02$; $P = 0.03$ respectively). Calves on the HD diet presented significantly lower mean log2 BVDV 1a serum neutralizing antibody titers in those time points compared with calves on the BD and GD treatment groups (Figure 14).

No weaning × backgrounding interaction ($P \geq 0.4$) was observed in the mean log2 BVDV 2a serum neutralizing antibody titers (Figures 15 and 16); however, there was a main treatment effect observed at D 28 and D 106. At D 28 abruptly weaned calves had a significantly lower mean log2 serum BVDV 2a antibody titer ($P = 0.0003$; Figure 15) compared with fenceline and nose-flap groups. At D 106, calves on the HD diet presented a significantly lower ($P = 0.0004$; Figure 16) mean log2 BVDV 2a titers compared with calves in the BD or GD groups.

Antibody response to vaccination in general, as well as the level of serum neutralizing antibodies to BVDV and BHV-1, provide a good approximation to vaccine efficacy and clinical protection against BRDC treatment in weaned beef calves (Fulton et al., 2002; Richeson et al., 2019; Fulton et al., 2020). Vaccination is a common preventative measure in combating diseases such as BRDC, but overall efficacy in these vaccines is inconsistent due to differing management practices across the beef industry (Richeson and Falkner, 2020; Chamorro and Palomares, 2020). Proper management surrounding vaccinations is important to vaccination efficacy, with stress and nutritional status being strong components to proper immune function (Richeson et al., 2019). Label guidelines from manufacturers recommend that vaccines should be administer to cattle at times of homeostasis. Stress has the capability of causing immunosuppression and increased risk of infectious disease in the animal. It is possible that the combination of stressors such as weaning, transport, and commingling reduce vaccination efficacy by reducing the ability of the animal to develop adequate humoral and cell mediated immune responses to vaccination and increasing the risk of disease at the feedyard (Richeson and Falkner, 2020). Differences observed at D28 across weaning methods suggest that stress associated with abrupt weaning could have affected the developing of complete immune responses to BVDV 2 in calves from that group. Hickey et al. (2003) reported abruptly weaned calves experienced decreased leukocyte concentrations and an increased in the neutrophil-to-lymphocyte ratio, which can be an indicator of subclinical infection and reduced efficacy of adaptive immunity including antibody synthesis and production. This supports that stress associated with weaning could directly affect adaptive immune responses. Differences in antibody levels during the backgrounding phase (D 88 and D 106) were observed in calves from the HD group. This change in antibody response coincides with an overall reduction in ADG of this group following D 58 (Figure 9). Hydration and nutritional status of the animal are important factors for developing the establishment of adequate and complete immune responses, and even a slight change in energy availability and dry matter intake could affect response to vaccination (Richeson et al., 2019). Although some differences in antibody response to vaccination were observed in this study, it is important to note that in general antibody responses to vaccination were within the expected range and are similar to other studies using the same vaccination protocol (Spore et al., 2018). The strong response in titers following the booster given at D 88 is similar to that observed by Tait et al. (2013). In this particular study, calves abruptly weaned following initial vaccination had a greater antibody titer response after a second dose of vaccine (booster) compared with calves abruptly weaned following booster vaccination. This suggests that providing a second dose of vaccine after abrupt weaning (stressful event) and initial vaccination could increase antibody titers before arrival of calves to the next productive stage (stocker or feedyard). The robust antibody response of all calves to BHV-1 following the booster with Pyramid5 and an autogenous vaccine that did not contain BHV-1 could have been the result of an increased antigenic stimulation provided by the adjuvant contained in the autogenous vaccine; however, other factor may have played a role and this warrants further investigation.

Transportation, Feedyard Performance and Carcass Merit

Calf performance response following transport to the feedyard in southwest Kansas are presented in Table 9. Neither weaning treatment or diet had a significant effect on BW pre-transport, 24 hr rest after arrival or on shrink loss ($P > 0.05$). Shrink is described as not only the loss of gut fill over time, but also the loss of body tissue and fluid and can be an indicator of health status as an animal is entering the feedyard (Coffey et al., 2001; Gonzalez et al., 2012). Animals were allowed to rest 24 hr with free choice access to water and hay. Weights were then recorded in order to determine differences in body tissue loss during the transportation event and not just gut fill loss. Shrink loss across all treatments are similar to those previously reported in the literature especially when one considers the long distance these animals traveled to the feedyard (Gonzalez et al., 2012). This distance traveled is common for Southeast U.S. cattle, with a majority of feedyards being in the Midwest or West U.S. region (Babcock et al., 2009).

Initial weights in the feedyard and weights at each weigh period over the course of the study are depicted in Table 10 by weaning and backgrounding treatment. There was no main effect or weaning × backgrounding interaction effect on body weights in the feedyard phase ($P \geq 0.10$). ADG was calculated between each weigh day to observe the changes in growth by calves (Figure 17). There was no weaning × backgrounding interaction or weaning effect in any stage of the feeding phase ($P \geq 0.10$). In the first period (35-days) there was a backgrounding effect observed in ADG ($P = 0.02$). Calves on the BD diet had a higher ADG at 2.1 kg/d compared to calves on the GD diet at 1.8 kg/d. This could be attributed to the calves making the transition from a pasture diet to a drylot diet. Following the D35 weigh in at the feedyard there were no other differences seen in ADG throughout the feedyard phase.

There was no weaning × backgrounding or main effect difference on health parameters in the feedyard (Table 11). There was a 20% morbidity rate total following treatments for BRDC. Animals that were treated at least once and then any relapses in treatment were recorded. In total, there were 7 deaths or animals sold prematurely attributed to respiratory disease, which resulted in an overall 3.3% death loss due to BRDC. Morbidity results caused by suspected BRDC are similar to both other studies (Richeson et al., 2015) and common industry trends (USDA, 2022). In 2013, the USDA predicted that over 16.2% of all cattle placed in the feedyard showed signs of BRDC and subsequently treated for such. Richeson et al. (2015) showed similar morbidity rates following a study with high-risk stocker calves but had a higher retreatment rate than the present study. Concerns with weaning management often centers around the health status of animals and affect disease has on feedyard performance and carcass characteristics. Arthington et al. (2005) similarly observed differences in weaning methods in early receiving and growing periods with no differences during the finishing period in growth and ADG. While no weaning treatment differences were seen in health status during the feeding phase in this study, alternative weaning methods have been shown to have a decrease in morbidity rate, with traditionally weaned calves experiencing twice the treatment rate for disease (Boyles et al., 2007). Research by Reinhardt et al. (2012) supports that the more times an animal is treated for disease, the more performance and carcass quality is affected. Similar results were observed by Schneider et al. (2009) in which increased incidence of disease greatly diminished carcass quality in a period from 2003 to 2006 in over 10 different feedyards.

There were no differences observed for hot carcass weight (HCW, *P* = 0.73), ribeye area (REA, *P* = 0.73; Table 12), marbling score (*P* = 0.19) calculated USDA Yield Grade (CYG, *P* = 0.89), percentage of carcasses that graded USDA Choice and Prime (*P* = 0.73) or backfat thickness (*P* = 0.74). Few experiments have evaluated the effects of weaning management and Southeast U.S. backgrounding diets on subsequent feedyard performance and carcass characteristics. Based on other trials evaluating differing backgrounding diets followed by feedyard finishing, results were similar to those observed in this study. Dietary differences during the backgrounding phase have a minimal effect on feedyard performance and carcass characteristics (Gadberry et al., 2012; Smith et al., 2020). Several studies including Kumar et al. (2012) saw no difference in prior diets containing forages on feedyard performance. Buttrey et al. (2012) also concluded no differences in carcass performance when steers were offered DDGs in the backgrounding phase. Studies such Cox-O'Neill et al. (2017) have shown differing performance in carcass traits in cattle on backgrounding diets of corn residue grazing, cover crop grazing, or drylot backgrounding methods but those are still minor differences.

Summary and Conclusions

Calves born in the Southeast are often at a disadvantage following weaning because of the stress associated with this production stage, commingling with other calves and long transportation events to feedyards (Babcock et al., 2009). All of these predisposing factors often lead to increased susceptibility to diseases such as BRDC. Management practices pre- and post-weaning can have a large impact on the performance and health of beef calves. In this study, weaning management methods had significant effects on performance and response to vaccination during the first 60 days post-weaning. This study also demonstrated that all three backgrounding diet systems provided to calves supported near target growth goals through the summer months. In this study, weaning management and backgrounding diet did not affect shrink post-arrival at the feedyard or subsequent feedyard performance and carcass quality measures.

It is also important to note that the calves used throughout this study were all sourced from university farms. Commingling of calves initially took place in the weaning period after vaccination of all animals, in the backgrounding period there was no commingling of calves from different sources. Commingling of calves can be overlooked as a major stressor that can affect vaccination responses and increase BRDC risk in weaned beef calves (Cooke, 2017). Further research is necessary to understand how practices such as marketing strategies after weaning (backgrounding vs. auction market), commingling of calves, backgrounding period length, and various nutritional practices can improve the transition of Southeastern beef calves to the next stages of production. The appropriate combination of weaning methods and backgrounding practices can not only help Southeastern cow-calf producers meet their production and profit goals, but could also translate to production success in the feedyard phase.

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Table 7. Chemical composition characteristics of conserved forages fed during a 60-d backgrounding trial for weaned beef calves.

Nutrient Analysis[1]	CSB[2]	BH[3]	WSA[4]	DDGS[5]
DM, %	36.6	88.3	--	90.2
CP	14.9	12.8	10.6	31.3
NDF	56.7	66.5	58.6	30.1
ADF	33.8	34.6	34.1	10.1
TDN	55.8	54.4	55.0	79.4

[1]Values reported on a % DM basis, based on analysis.

[2]CSB = cool-season annual baleage.

[3]BH= Tifton 85 bermudagrass hay fed.

[4]WSA = warm-season annual mixture used for grazing.

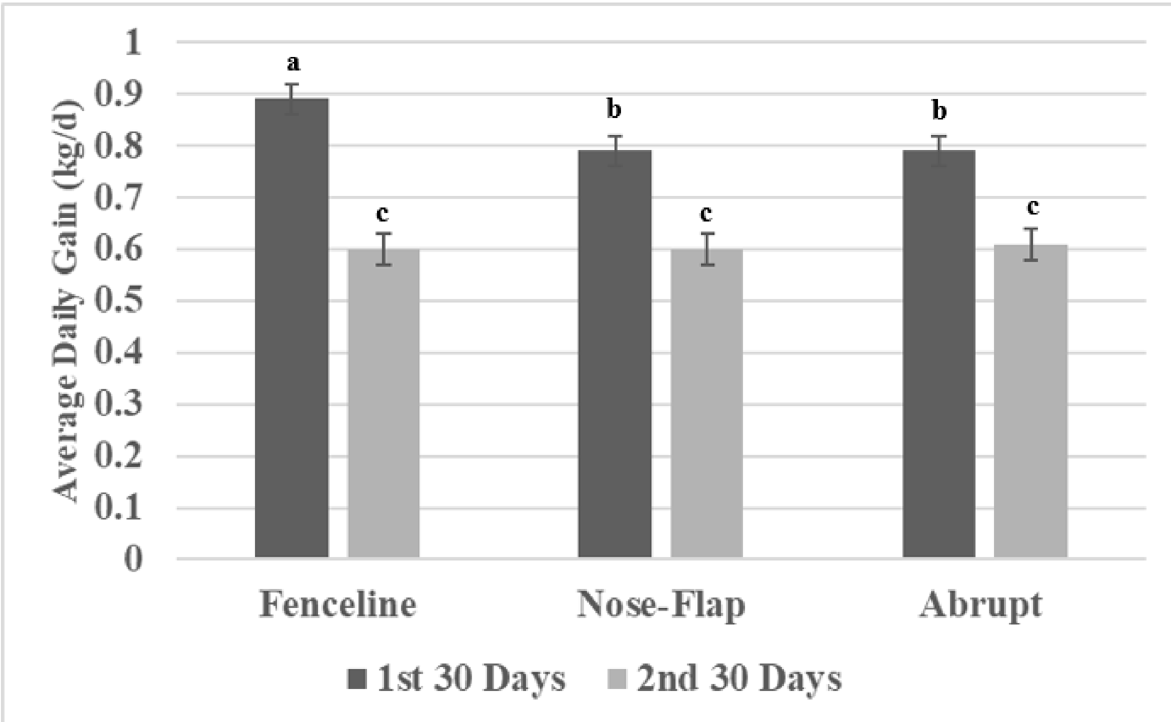
[5]DDGS = dried distillers grains with solubles.

Table 8. Mean body weight (kg) of beef calves at D21 of study and during the 60-d backgrounding period.

Weaning method[1]	Fenceline			Nose-Flap			Abrupt			SEM	*P*
Diet[2]	BD	HD	GD	BD	HD	GD	BD	HD	GD	--	--
Unit	--BW, kg---									-	-
D21	296.1	301.3	292.9	290.7	298.8	285.2	297.7	296.6	289.8	3.8	0.96
D28	304.6	300.2	299.6	296.6	298.8	297.9	308.4	297.4	295.5	3.5	0.80
D58	331.0	329.3	324.5	319.5	327.4	317.6	326.8	330.4	315.4	3.6	0.88
D88	350.6	341.4	346.5	342.2	333.2	343.1	351.3	340.2	336.9	3.6	0.78

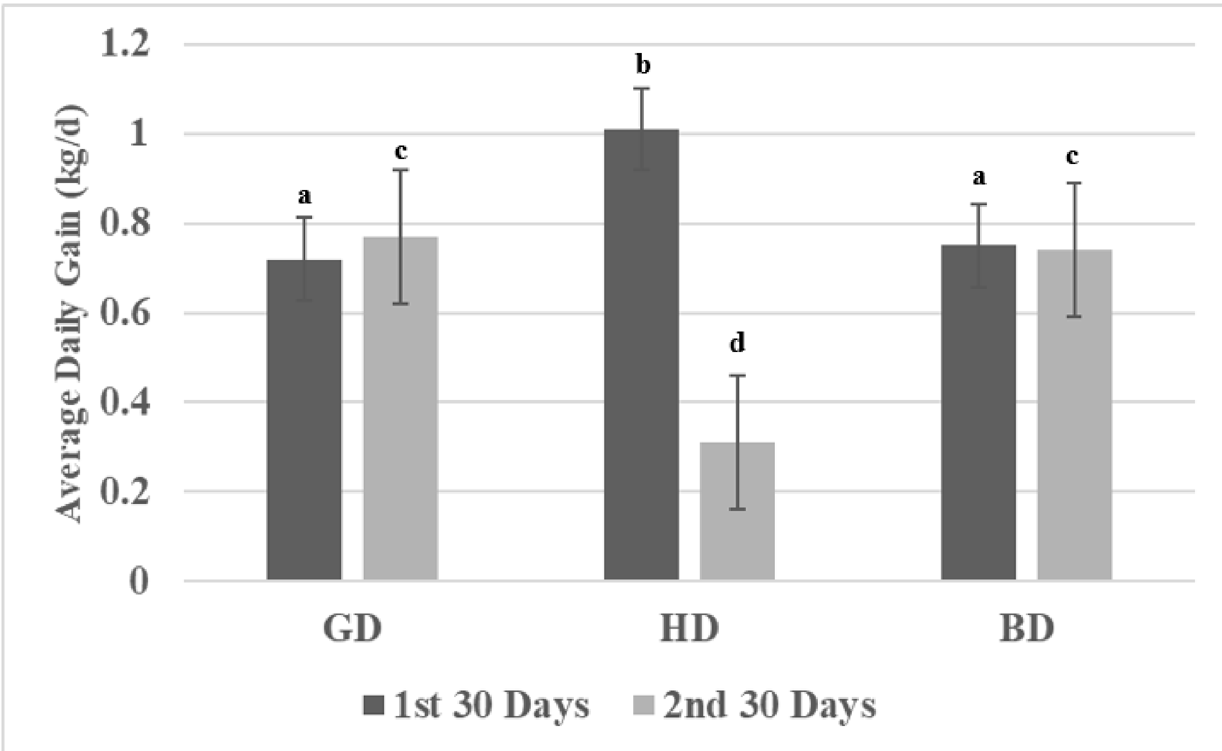
[1]Weaning method during the weaning period.
[2]Backgrounding period diets are defined as BD = cool season annual baleage with 1% of animal body weight per day of dried distillers grains; HD = bermudagrass hay with 1% of animal body weight per day of dried distillers grains; GD = grazing of warm season annual mixture with 1% of animal body weight per day of dried distillers grains.

Figure 8. Weaning method effects (1st 30 Days, $P = 0.02$; 2nd 30 Days, $P = 0.82$) on mean average daily gain (kg/d) of beef calves during a 60-d backgrounding period (SE = 0.03).



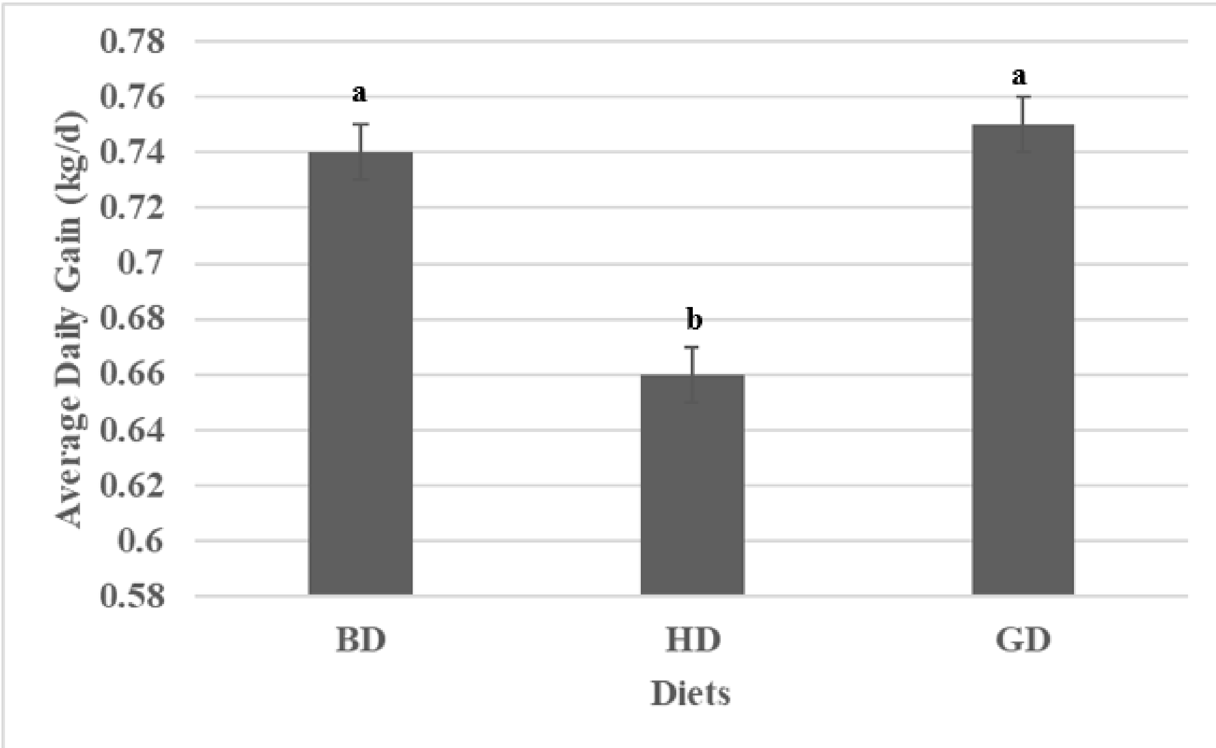
[abc] Denotes differences in weaning methods during each period ($P < 0.05$).

Figure 9. Backgrounding diet effects (1st 30 Days, *P* <0.0001; 2nd 30 Days, *P* <0.0001) on mean average daily gain (kg/d) of beef calves during the 60-d period (SE = 0.03).



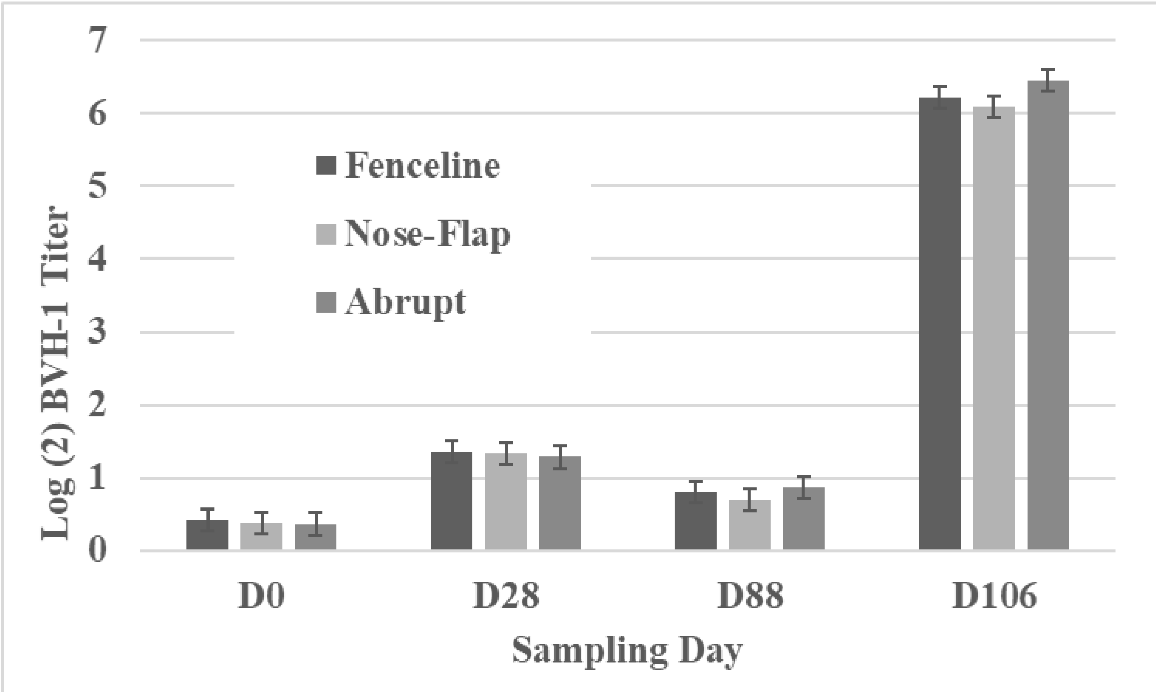
[abcd] Denotes differences in backgrounding diet during each period ($P < 0.05$).

Figure 10. Backgrounding diet effects ($P = 0.002$) on mean average daily gain (kg/d) of calves during the 60-d backgrounding period compared across backgrounding diets.



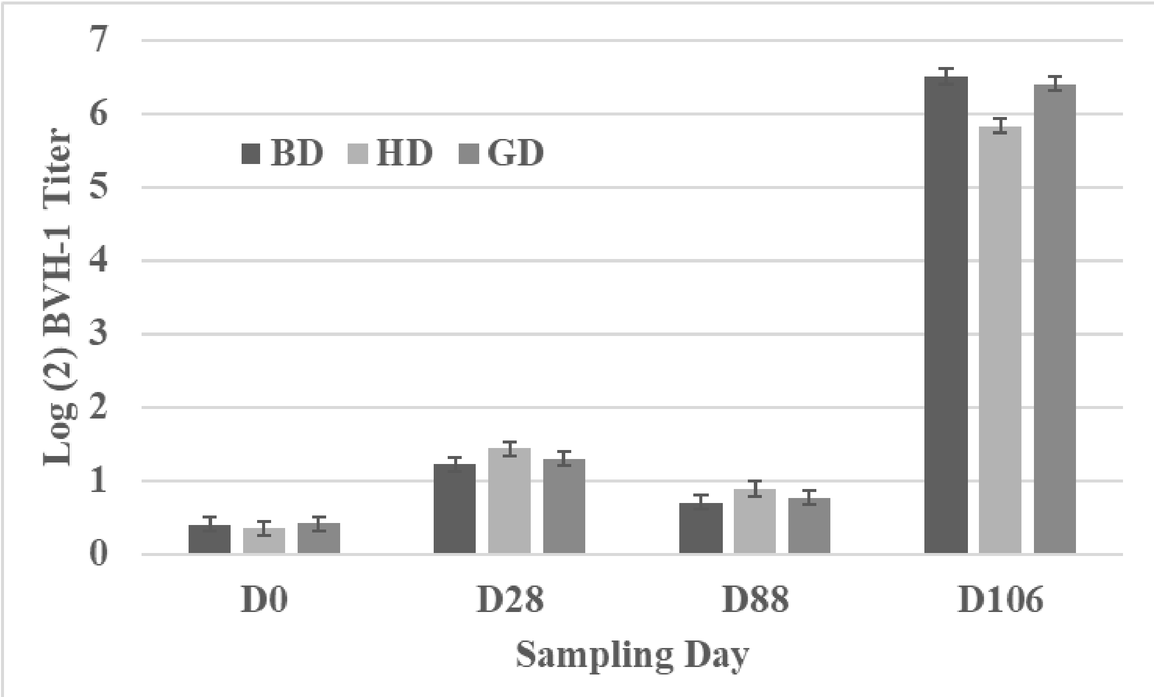
[ab] Denotes differences in backgrounding diet ($P < 0.05$).

Figure 11. Effects of weaning method on infectious bovine herpesvirus 1 (BVH-1) viral neutralizing antibody titers in serum after vaccine administration on D0, and D88.



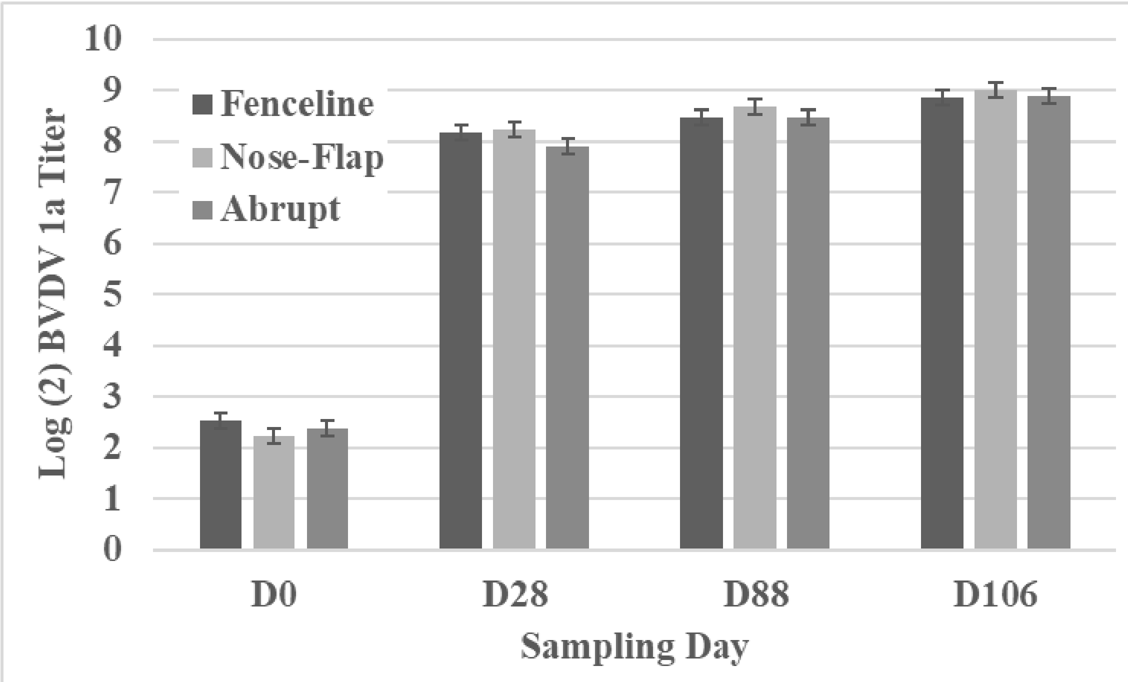
D0- Initiation of study at weaning. Pyramid® 5 Vaccine given (*P* = 0.87).
D28- Beginning of backgrounding period (*P* = 0.91).
D88- End of backgrounding period. Pyramid® 5 booster and autogenous vaccine given (*P* = 0.41).
D106- 3 days prior to shipment to feedyard (*P* = 0.26).

Figure 12. Effects of backgrounding diet on infectious bovine herpesvirus 1 (BVH-1) viral neutralizing antibody titers in serum after vaccine administration on D0, and D88.



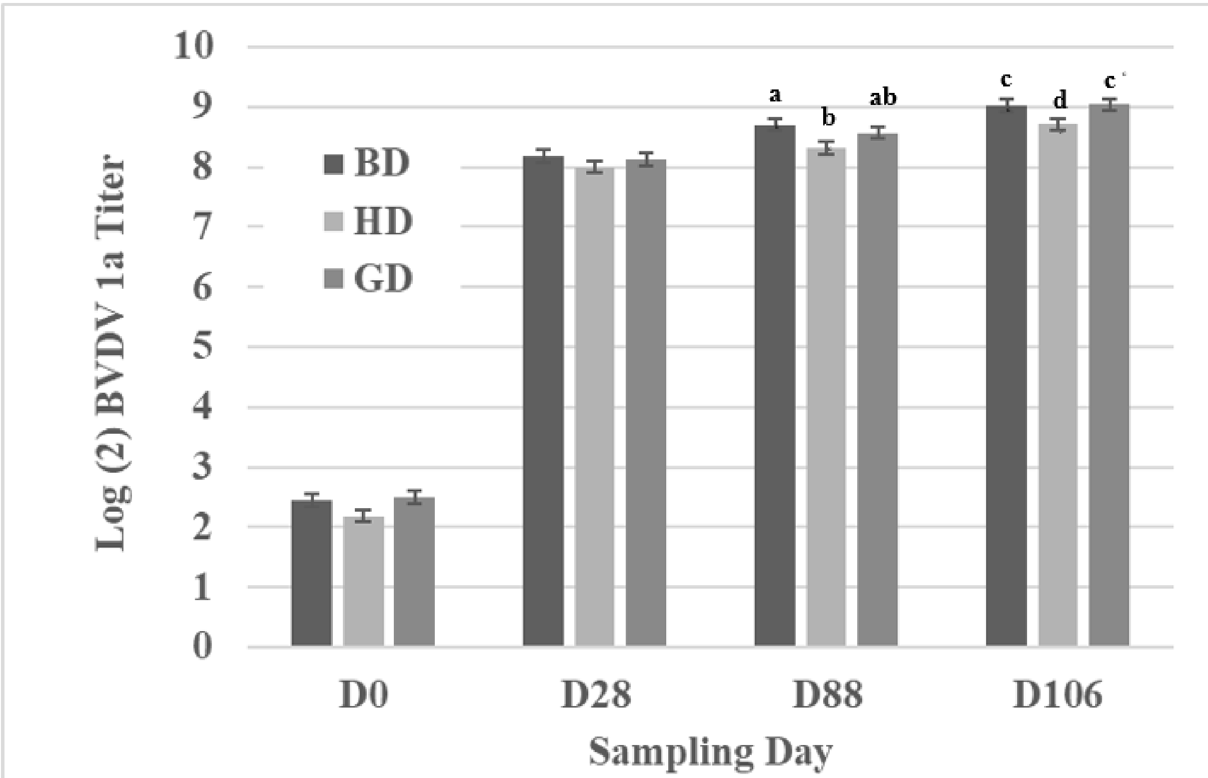
[ab] Denotes difference in titer response by backgrounding diet at each time point (*P* < 0.05).
D0- Initiation of study at weaning. Pyramid® 5 Vaccine given (*P* = 073).
D28- Beginning of backgrounding period (*P* = 0.41).
D88- End of backgrounding period. Pyramid® 5 booster and autogenous vaccine given (*P* = 0.41).
D106- 3 days prior to shipment to feedyard (*P* = 0.004).

Figure 13. Effects of weaning method on infectious bovine viral diarrhea virus (BVDV) 1a viral neutralizing antibody titers in serum after vaccine administration on D0, and D88.



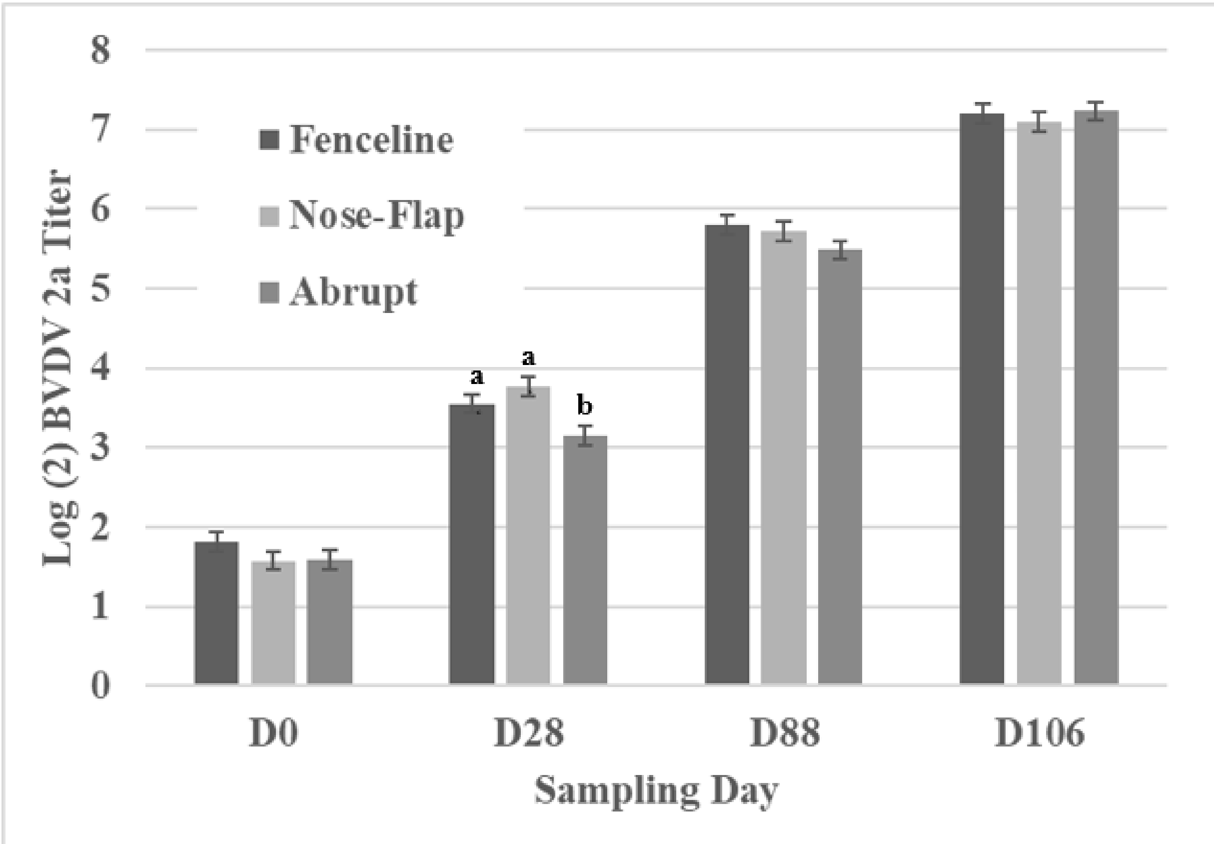
D0- Initiation of study at weaning. Pyramid® 5 Vaccine given (*P* = 0.43).
D28- Beginning of backgrounding period (*P* = 0.08).
D88- End of backgrounding period. Pyramid® 5 booster and autogenous vaccine given (*P* = 0.23).
D106- 3 days prior to shipment to feedyard (*P* = 0.62).

Figure 14. Effects of backgrounding diet on infectious bovine viral diarrhea virus (BVDV) 1a viral neutralizing antibody titers in serum after vaccine administration on D0, and D88.



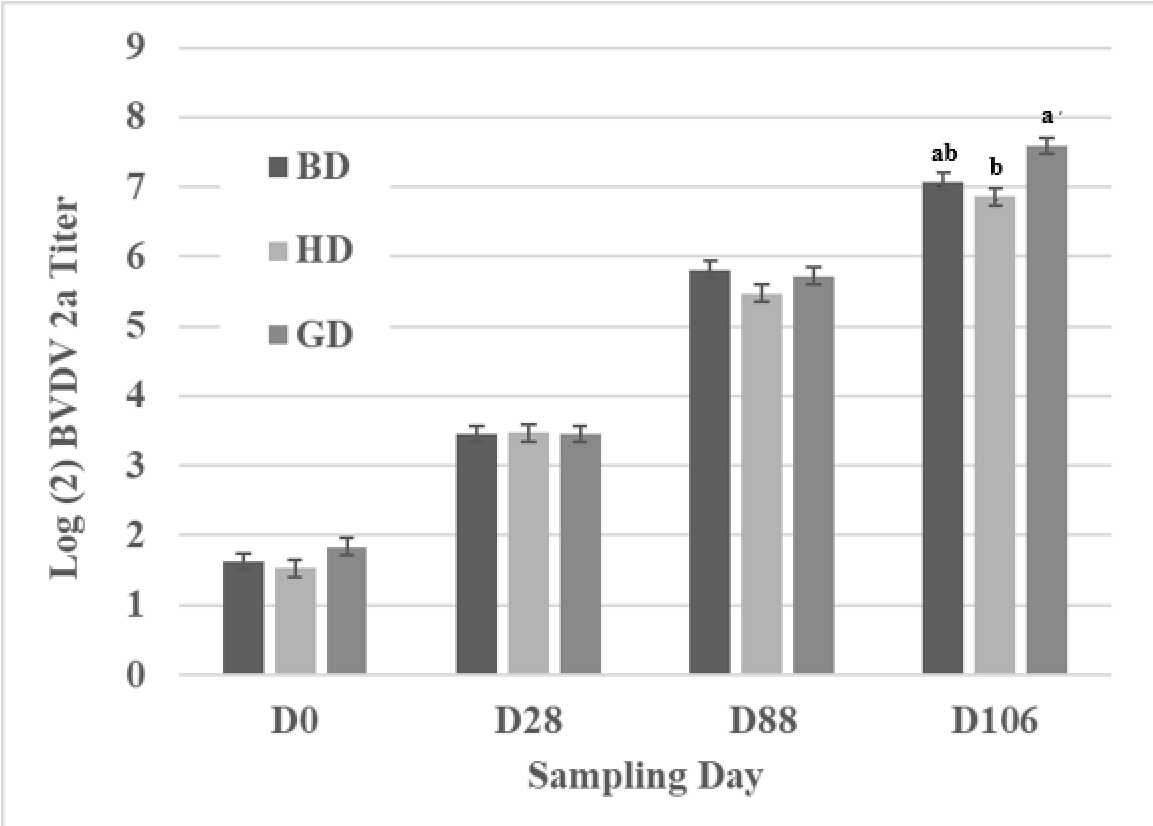
[abcd] Denotes difference in titer response by backgrounding diet at each time point (P < 0.05).
D0- Initiation of study at weaning. Pyramid® 5 Vaccine given (P = 029).
D28- Beginning of backgrounding period (P = 0.48).
D88- End of backgrounding period. Pyramid® 5 booster and autogenous vaccine given (P = 0.02).
D106- 3 days prior to shipment to feedyard (P = 0.03).

Figure 15. Effects of weaning method on infectious bovine viral diarrhea virus (BVDV) 2a viral neutralizing antibody titers in serum after vaccine administration on D0, and D88.



[ab] Denotes difference in titer response by weaning method at each time point ($P < 0.05$).
D0- Initiation of study at weaning. Pyramid® 5 Vaccine given ($P = 0.40$).
D28- Beginning of backgrounding period ($P = 0.0003$).
D88- End of backgrounding period. Pyramid® 5 booster and autogenous vaccine given ($P = 0.13$).
D106- 3 days prior to shipment to feedyard ($P = 0.74$).

Figure 16. Effects of backgrounding diet on infectious bovine viral diarrhea virus (BVDV) 2a viral neutralizing antibody titers in serum after vaccine administration on D0, and D88.



[ab] Denotes difference in titer response by backgrounding diet at each time point ($P < 0.05$).
D0- Initiation of study at weaning. Pyramid® 5 Vaccine given ($P = 0.27$).
D28- Beginning of backgrounding period ($P = 0.86$).
D88- End of backgrounding period. Pyramid® 5 booster and autogenous vaccine given ($P = 0.11$).
D106- 3 days prior to shipment to feedyard ($P = 0.0004$).

Table 9. Backgrounding effects ($P > 0.05$) on beef calf body weight (kg) and percentage of body weight shrink loss (%) following transport from Shorter, AL to Montezuma, KS.

Diet[1]	BD	HD	GD	SEM	*P*
Pre-Transport BW[2], kg	343.5	348.9	340.6	3.5	0.22
24 h Rest BW[3], kg	331.6	336.0	333.6	3.4	0.67
Shrink Loss (%)[4]	3.7	4.8	3.6	0.5	0.12

[1]Backgrounding period diets are defined as BD = cool season annual baleage with 1% of animal body weight per day of dried distillers grains; HD = bermudagrass hay with 1% of animal body weight per day of dried distillers grains; GD = grazing of warm season annual mixture with 1% of animal body weight per day of dried distillers grains.

[2]Pre-Transport observations were taken 3-days prior to shipment when calves were being sorted into their feedyard groups.

[3]24 h Rest Observations are those taken after animals were allowed to rest with access to hay and water for 24 h after arrival

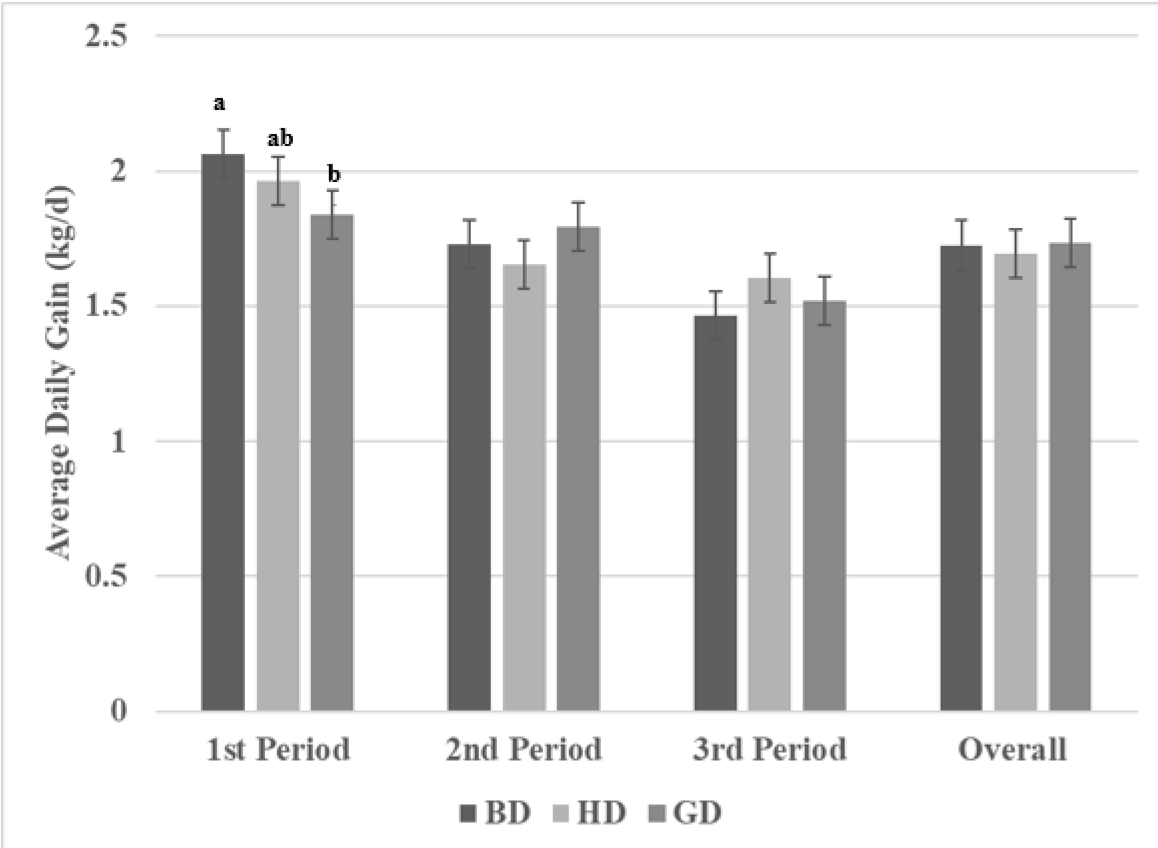
[4]Shrink Loss is the percentage of weight loss between Pre-Transportation and 24 h Rest of the original Pre-Transport weight.

Table 10. Weaning method and backgrounding diet effects on mean body weight (kg) of beef calves during the feedyard phase.

Weaning Treatment[1]	Fenceline			Nose-Flap			Abrupt			SEM	*P*
Diet[2]	BD	HD	GD	BD	HD	GD	BD	HD	GD	--	--
Unit	----------BW, kg----------									-	-
D0	333.7	337.6	335.9	322.9	329.6	331.0	338.3	340.6	334.5	4.2	0.91
D35	402.5	404.5	399.3	393.7	400.8	398.6	417.0	408.0	394.7	4.1	0.44
D100	529.3	526.6	532.3	525.4	525.7	522.4	547.0	528.8	524.7	4.4	0.50
Final Est. Weight[3,4]	651.6	655.4	659.7	651.0	658.3	660.7	679.2	647.8	647.6	5.6	0.15

[1]Weaning method during the weaning period.
[2]Backgrounding period diets are defined as BD = cool season annual baleage with 1% of animal body weight per day of dried distillers grains; HD = bermudagrass hay with 1% of animal body weight per day of dried distillers grains; GD = grazing of warm season annual mixture with 1% of animal body weight per day of dried distillers grains.
[3]Includes Year 1 data only at this time.
[4]Final estimated weight were estimated based on the actual individual hot carcass weight of the animal and the dressing percentage of the entire group.

Figure 17. Backgrounding diet effects on average daily gain across feedyard periods until harvest.



[ab] Denotes difference in titer response by backgrounding diet at each time point ($P < 0.05$).
1[st] Period- Arrival at feedyard to D35 ($P = 0.02$).
2[nd] Period- D35 to D100 at feedyard ($P = 0.74$).
3[rd] Period- D100 to harvest- Year 1 data only ($P = 0.49$).
Overall- Year 1 data only ($P = 0.84$).

Table 11. Morbidity percentage and mortality rates of beef calves in the feedyard phase based on weaning method or backgrounding diet during Year 1 of study.

Weaning Method[1]	FL	NF	AB	*P*
Number of Animals	70	72	65	--
1 Treatment (%)[3]	25.7	18.1	15.4	0.64
≥ 2 Treatments (%)[4]	33.3	38.5	51.9	0.64
Death Loss[5]	4	2	1	0.38
Diet[2]	**BD**	**HD**	**GD**	
Number of Animals	69	69	69	--
1 Treatment (%)	18.8	15.9	24.6	0.49
≥ 2 Treatments (%)	69.2	63.6	17.6	0.49
Death Loss	3	3	1	0.55

[1]Weaning Method during the weaning period; FL= Fenceline, NF= Nose-Flap, and AB = Abrupt.
[2]Backgrounding period diets are defined as BD = cool season annual baleage with 1% of animal body weight per day of dried distillers grains; HD = bermudagrass hay with 1% of animal body weigh per day of dried distillers grains; GD = grazing of warm season annual mixture with 1% of animal body weight per day of dried distillers grains.
[3]Percentage of animals who received at least one treatment for BRDC.
[4]Percentage of animals treated who received 2 or more treatments for BRDC.
[5]Number of animals sold prematurely or died dur to BRDC related causes.

Table 12. Carcass characteristics of beef calves backgrounded on various southeastern U.S. diets.

Diet[1]	BD	HD	GD	SEM	*P*
% Choice[2]	85	82	79	31	0.73
Marbling[3]	471.2	467.4	448.6	9.3	0.19
CYG[4]	1.4	1.4	1.4	0.1	0.89
HCW, kg	424.3	420.2	421.3	3.7	0.73
Backfat, cm[5]	1.6	1.6	1.5	0.1	0.74
REA, cm^2 [6]	97.4	98.5	97.3	1.3	0.73

[1]Backgrounding period diets are defined as BD = cool season annual baleage with 1% of animal body weight per day of dried distillers grains; HD = bermudagrass hay with 1% of animal body weigh per day of dried distillers grains; GD = grazing of warm season annual mixture with 1% of animal body weight per day of dried distillers grains.
[2]Percentage of carcasses that were graded USDA Choice or USDA Prime
[3]Marbling Score 300-399 = Slight, 400-499 = Small, 500-599 = Modest degrees of marbling in the *L. dorsi* when observed at the break between the 12th and 13th rib.
[4]The unrounded calculated USDA Yield Grade.
[5]Thickness of the subcutaneous fat at the break between the 12th and 13th rib, measured in centimeters.
[6]Ribeye area is the area of the *L. dorsi* in square centimeters at the break between the 12th and 13th rib of the carcass.

Chapter 5: Summary and Conclusions

Beef cattle producers in the Southeast U.S. can use forage-based systems for management of beef calves during the post-weaning period. By utilizing both warm-season and cool-season forage systems, producers have the opportunity to capitalize on highly productive forage systems that can adequately meet the nutritional needs of growing cattle in more advantageous economic conditions (Ball et al., 2015; Gadberry et al., 2016). Beef calves are typically sold on a kg of body weight basis, and the weight of the calf sold is an extremely important factor when looking at the small margin of returns that producers are often facing (McBride and Mathews, 2011; Hilton, 2015). However, the majority of calves from the Southeast are eventually transported long distances to the mid-west region of the U.S. to be finished in the feedyard and eventually harvested. This transition is met with major stressors such as long transportation events, commingling with animals of different origin, nutritional changes, and of course significant growth (Wilson et al., 2017). Weaning and backgrounding management practices continue to represent potential points of intervention to ease the transition of calves into different sectors of the industry and are strategies that can be adopted in the Southeast region to improve overall beef production chain viability.

In this set of studies, weaning management had notable carryover effects in the first 60-days post weaning. Overall, fenceline calves had an advantage over the other two weaning management systems evaluated despite demonstrating greater weight lost following transportation at the end of the weaning period. Based on animal performance and immune response parameters measured in this study, fenceline weaning may be a method for use by Southeast U.S. beef producers. Fenceline weaning could provide benefits reducing weaning stress and improving performance and health during the early post-weaning and backgrounding periods.

In the backgrounding period, all three of the backgrounding diet systems supported growth in the calves throughout the summer months, with differences observed in terms of diet transition. Calves on the hay (HD) diet had better growth performance in the first half of the backgrounding period compared to the other two diets. However, in the second half of the backgrounding period the baleage (BD) and grazing (GD) diets had greater gains. The interaction of weaning method and backgrounding diet illustrated that time of retention of animals post-weaning is a key factor for producers to consider. Nose-flap and abruptly weaned calves given enough time to settle into their environment during the backgrounding phase were able to compete with the fenceline weaned calves in terms of animal gain. However, if a producer is looking to sell quickly after weaning, fenceline weaning may be a more viable option due to the fact that, there may be more kg of body weight to take advantage of at the time of marketing. In the backgrounding system again, if a producer is planning to keep calves for a longer period of time, the GD or BD diets may be more advantageous to capitalize on greater gains at the end of the backgrounding period. Additionally, supplementation strategies may be adjusted to reach additional target gain goals. In contrast, if a producer is planning to background calves for a shorter amount of time (<60 days), the HD may be more be better suited for transition. Future research should be designed to evaluate the length of post-weaning management period and how these different management styles can impact performance. However, results in the feedyard phase indicated that in this system through an 88-d post weaning period, effects of post-weaning management dissipated within the first 30-d in the feedyard.

It is also important to not look over factors in this study that could not be pertained to real world situations. All of the calves in this study were sourced from university farms. These are well managed closed herds, with a known health history and the vaccination protocol was controlled, which would be more representative of responses observed among farms retaining and backgrounding home-raised calves. These calves were never truly commingled with animals from different origins until they entered the feedyard. Commingling of calves during this period can often be overlooked as a major contributor of BRDC (Cooke, 2017). Future research should focus on how these methods could impact the performance of true high-risk stocker cattle.

Results from this survey indicate that while there are many different management strategies used across cow-calf production systems in the Southeast, a majority of producers are facing similar issues, and this could impact how they make their management decisions. Along with decreasing land availability, many producers are struggling with rising input costs and continued variability in the market. Lack of knowledge of marketing strategies used in backgrounded calves is another source of concern. Often producers do not understand the premiums that could be received for backgrounded or precondition cattle, leading them to believe that the extra costs involved with these programs is not worth the risk in their profits. The results from this set of studies, others like it and future projects on methods to reduce weaning stress and improve beef calf performance in all sectors can ultimately lead to producers making the best management decisions for their own operations.

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Appendix 1. Weaning and Backgrounding Management Practices Survey

1. What is the zip code for your operation?

2. Which of the following best describes your cattle operation?
    a. Commercial cow-calf
    b. Purebred cow-calf
    c. Stocker/backgrounder
    d. Commercial and purebred cow-calf
    e. Cow-calf and stocker
    f. Other- please specify

3. How many cows do you calve out each year?
    a. 25 head or less
    b. 26-50 head
    c. 51-100 head
    d. 101-200 head
    e. More than 200 head

4. What would you consider your calving season to be (select all that apply)?
    a. Spring (March-May)
    b. Fall (October-December)
    c. Winter (January-March)
    d. I don't have a defined calving season.

5. Rank the following list of challenges from most relevant to least relevant as they apply to your beef cattle operation.
    a. Land availability
    b. Input costs
    c. Lack of market predictability
    d. Lack of marketing options
    e. Sickness/disease
    f. Facilities
    g. Stress from transportation/handling
    h. Labor
    i. Wildlife predation

6. In general, what do you do with your bull calves post-weaning (Select all that apply)?
    a. Sell at weaning
    b. Develop and retain for personal use
    c. Develop and sell as breeding stock
    d. I do not sell bulls

7. In general, what do you do with your steer calves post-weaning (Select all that apply)?
    a. Sell at weaning
    b. Background/precondition

c. Retain through finishing
d. I do not castrate my calves

8. In general, what do you do with your heifer calves post-weaning (Select all that apply)?
    a. Sell at weaning
    b. Develop and retain for personal use
    c. Develop and sell as breeding stock
    d. Background/precondition
    e. Retain through finishing

9. How would you describe your method of calf weaning in your operation?
    a. Abrupt (conventional) – calves are abruptly removed from the dam's side and completely separated.
    b. Fenceline- cows and calves are separated for a set time through only a fenceline. Contact of some form is still present.
    c. Nose-flap- a nose-flap (i.e., Quiet Wean) is put in to prevent calves from suckling from their dam. Calves remain with dam for a period of time.
    d. Other- please specify

10. Do you precondition or background your calves after your weaning period?
    a. Yes (in most years)
    b. Sometimes (in some years but not others)
    c. No

    *Backgrounding is the growing of steers and heifers from weaning or preconditioning until they enter the feedlot for finishing.

Here is where the survey splits. In question 9 if the participant answers Yes or Sometimes they will continue on to 13 through 23. If the participant answers No they will only answer questions 10 through 12 and then the survey will end for them.

1. If no, why do you NOT background your calves (select all that apply)?
    a. Time
    b. Labor
    c. Facilities
    d. Costs
    e. Land or Acreage
    f. Market
    g. Lack of understanding on backgrounding/preconditioning programs
    h. Other (fill in the blank)

2. If no, what changes may make you consider backgrounding your calves?
3. Prior to sale, what management practices do you follow (select all that apply)?
    a. Wean at least 30 days
    b. Wean at least 45 days
    c. Wean at least 60 days
    d. Wean at least 90 days

e. Vaccinate
c. Castrate
d. Implant
e. Other- please specify

4. What is your experience with backgrounding calves (select all that apply)?
   a. I typically background my own calves following weaning.
   b. Purchase calves to background.
   c. Custom background calves for others.
   d. Other- please specify

5. When marketing calves after backgrounding, do you:
   a. Direct market
   b. Local livestock auction
   c. Local special sale (board sale, etc)
   d. Online auction
   e. Retain ownership through feedyard
   f. Other (fill in the blank)

6. Prior to sale, what management practices do you follow (select all that apply)?
   f. Wean at least 30 days
   g. Wean at least 45 days
   h. Wean at least 60 days
   i. Wean at least 90 days
   j. Vaccinate
   d. Castrate
   e. Implant
   f. Other- please specify

7. Which of the following forms of animal identification methods do you currently use (click all that apply)
   a. None
   b. Plastic ear tag
   c. Metal tag (I.e. brucellosis tag, state veterinarian tag etc.)
   d. Electronic ear tag (RFID)
   e. Hot Brand
   f. Freeze Brand
   f. Ear notches
   g. Other- please specify

8. What type of grazing management strategies do you typically use on your farm during the backgrounding phase? (check all that apply)?
   a. No grazing – I custom feed commodities and stored forages such as hay, baleage or silage.

b. Continuous grazing (cattle are allowed continuous access to pasture- otherwise no management)
c. Rotational grazing (cattle are rotated through pastures allowing pastures time for rest and regrowth)
d. Mob grazing (allowing cattle to graze small areas at heavy stocking densities- long rest periods between grazing events)
e. Other- please specify

9. Do you utilize conserved forage sources (i.e. hay, baleage, silage)
    a. Yes – this is the primary way I provide forage during backgrounding.
    b. Sometimes – I use stored forages to supplement when grazing is not as available.
    c. No

10. What types of forages do you typically use as part of backgrounding?
    a. Warm-season perennials (bermudagrass, bahiagrass, dallisgrass)
    b. Warm-season annuals (Crabgrass, millets, sorghums, etc)
    c. Cool-season perennials (Tall fescue)
    d. Cool-season annuals (Ryegrass, wheat, oats, triticale, annual clovers, etc)
    e. Other – please specify

11. Do you regularly soil test your pastures and hayfields for soil fertility?
    a. Yes
    b. No

12. Do you regularly have your forage tested for nutritional value?
    a. Yes
    b. No

13. How do you provide supplemental feed to calves during backgrounding?
    a. Free-choice feeder (I.e. self-fed)
    b. Hand-feeding daily
    c. Hand-feeding a few times per week
    d. I do not supplement

14. What type of supplemental feedstuff do you provide to calves during backgrounding (DDGS, whole cottonseed, pelleted feed, etc)? Please be specific as possible (i.e. brand, distributer etc)

Appendix 2. Weaning and Backgrounding Management Project Timeline

Timeline	Study Measures
Day 0	• Weights • Vaccines • Blood sampling • Transportation-AB[1]
Day 1	• Weights • Blood sampling -AB
Day 3	• Blood sampling - AB
Day 7	• Blood sampling - AB
Day 14	• Weights • Blood sampling • Transportation- FL, NF
Day 15	• Blood sampling -FL, NF
Day 17	• Blood sampling -FL, NF
Day 21	• Weights • Blood sampling -FL, NF
Day 28	Start of backgrounding- • Weights • Blood sampling • Vaccines
Day 58	• Weights
Day 88	• Weights • Vaccines • Blood sampling
Day 106	• Weights • Sorted
Day 109	Transport to KS Feedyard

[1]Weaning Treatments are defined as FL= Fenceline Weaning; NF = Nose-flap weaning; AB = Abrupt Weaning