EFFECTS OF MULTI-VALENT VACCINE TREATMENT AND TEMPERAMENT ON FEED INTAKE, PERFORMANCE, AND FEEDING BEHAVIOR RESPONSES TO BVD VIRAL CHALLENGE IN BEEF STEERS

A Thesis

by

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ABSTRACT

The objectives of this study were to examine the effects of vaccine treatment (**VT**) and temperament on DMI, performance, and feeding behavior responses to a BVD viral challenge. Nellore-Angus crossbred steers (N =360; initial BW 330 ± 48 kg) were assigned to 1 of 3 vaccine treatments: non-vaccinated (**NON**), modified live (**MLV**), and killed (**KV**). Performance, DMI, and feeding behavior traits were monitored for 56 d during 4 14-d periods, using a GrowSafe® system. All steers were inoculated intranasally with a BVDV type 1b at the end of the first 14-d period. Exit velocity (**EV**) was measured on days 0 and 14 and the average was used to compute initial relative exit velocity (**REV**), which was used to examine the effects of temperament. As expected, DMI, ADG, G:F, and frequency and duration of feeding events all decreased ($P < 0.01$) during period 2 following BVD viral challenge and subsequently increased during period 3. Average daily gain and G:F were not affected by vaccine treatment or the VT x period. However, the reduction in DMI following BVD viral challenge was less ($P < 0.05$) for MLV-vaccinated steers compared to KV- and NON-vaccinated steers. There were no VT x period interactions for any of the feeding behavior responses. Vaccine treatment clearly altered feeding behavior responses, such that MLV-vaccinated steers had greater ($P < 0.01$) duration of feeding events, meal frequency, and slower ($P < 0.01$) eating rates compared to KV- and NON-vaccinated steers. In general, calm steers (initial REV – 1 SD) had lower DMI, ADG, and G:F compared to excitable steers (initial REV + 1 SD). Temperament affected feeding behavior responses such that, calm steers had greater feeding duration and slower eating rates compared to excitable steers. With the

exception of meal frequency, VT x initial REV interactions indicate there were greater differences between vaccine treatments within calm steers compared to excitable steers. Overall the results of the current study suggest that the MLV vaccine mitigated the negatives effects of the BVD vial challenge to a greater extent than the KV vaccine, which corresponds with previous findings regarding immune responses.

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TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

Page

CHAPTER I

INTRODUCTION AND LITERATURE REVIEW

Introduction

Bovine Respiratory Disease (BRD) is one of the most costly and prevalent diseases affecting the cattle industry (Griffin, 1997; Smith, 1998), caused by both viral and bacterial pathogens (Ellis, 2001). Bovine respiratory disease can be attributed to 70-80% of morbidity and 40-50% of mortality in U.S. feedlots (Smith, 1998; Edwards, 2010). The economic cost of cattle with BRD can be attributed to a combination of treatment costs and a costs associated with the loss in production an animal incurs. Despite the fact that vaccines are used in 96% of feedlot cattle (NAHMS, 2013a) and that the advances in the prevention and treatment of BRD in feedlots over the years, little progress has been made in reducing the morbidity and mortality rates of BRD (Griffin, 1997; Smith, 1998; Edwards, 2010); in fact the incidence of BRD has been shown to be on the rise (Loneragan et al., 2001).

The lack of progress in the reducing the incidence of BRD may be attributed to low sensitivity in disease detection methods, the fact that vaccination against BRD, tend to have variable efficacy due to the variance in strains of both viral and bacterial pathogens (Grooms et al., 2014), or the fact that it is still more economic to purchase high risk cattle over preconditioned cattle (Ives and Richeson, 2015). Preconditioned calves are better prepared for the transition into the feed yard compared to calves that were not preconditioned (Ives and Richeson, 2015). Additionally, even though vaccines are used in the majority of feedlots, vaccination upon arrival, when the animal is stressed the stress response may not allow for a proper immune response compared to vaccination prior to arrival. The purpose of this review was to examine current literature regarding the economic costs associated with BRD, vaccination against BRD, and the effects of temperament on intake, performance, and immune function.

Economics associated with BRD

It is widely known that morbid cattle do not perform or gain as well as their healthy counterparts. This poor performance of morbid animals compared to healthy animals has direct effect on the economics of an operation. Several studies have shown that cattle that have been identified as sick tend to have a lower net return due to a number of factors such as, treatment costs, loss of production, and reduction in carcass quality at slaughter (Griffin, 1997; Smith, 1998; Fulton et al., 2002; Snowder et al., 2006; Cernicchiaro et al., 2013). According to the National Animal Health Monitoring System (NAHMS), the average cost of treating one case of BRD was $23.60, which was found to be independent of feedlot capacity (NAHMS, 2013b). Griffin (1997) estimated that the total cost of BRD to be about 7% of the total production costs for a morbid animal. Snowder et al. (2006), estimated that the economic cost of an animal with BRD to be $13.90 per animal, this included costs associated with loss in gains and treatment costs but did not include labor costs.

Animals identified as being sick are typically administered antimicrobial therapy, in order to help the animal get better and minimize losses in production. However, the number of treatments an animal receives not only has an effect on an economic basis but also has an effect on production traits such as ADG, hot carcass weight, and carcass yield grade. Fulton et al. (2002), examined the effect of the health status of calves and its impact on feedlot performance in a retained ownership scenario. They found that the net profit of a calf to the owner to be \$365 to \$677 (carcass value – feedlot costs). However, this net return was greatly impacted by the number of treatments a calf received. Calves that were treated once decreased profitability by \$40.64 and calves that were treated twice or ≥ 3 times reduced the profitability by \$58.35, and \$291.93, respectively. In addition, Cernicchiaro et al. (2013) examined the economic costs associated with the number of treatments an animal receives after diagnosis of BRD. Cattle that had been treated for BRD (1 to ≥3 times) had lower net returns (\$17.79 to \$-45.52) compared to cattle that had never been treated for BRD (\$30.37). Similar results were also reported by Schneider et al. (2009) regarding a decrease in net returns for cattle that have been treated for BRD compared to cattle that had never been treated for BRD.

Animals that had been treated for BRD typically had lower net returns, which may be attributed to losses in production, compared to animals that had never been treated. Production losses for an animal can be defined as but not limited to, a reduction in the ADG, a decrease in hot carcass weight (HCW), and/or a decrease in USDA carcass quality grade (Fulton et al., 2002; Snowder et al., 2006; Schneider et al., 2009; Cernicchiaro et al., 2013). Snowder et al. (2006), reported that animals with BRD had lower ADG (0.95 kg/d) compared to healthy animals (0.99 kg/d). Cernicchiaro et al. (2013) reported that ADG and HCW decreased as the number of BRD related treatments increased compared to animals that were never treated for BRD. Schneider et al. (2009) reported that cattle treated for BRD had lower overall ADG (1.37 kg/d) compared to cattle that had never been treated for BRD (1.44 kg/d). Additionally, Schneider et al. (2009) reported that cattle treated for BRD had an 8.2 kg reduction in HCW at slaughter compared to cattle that had never been treated for BRD.

In addition to the reduction in ADG and the loss in HCW, cattle identified with BRD also had a lower carcass quality grades compared to healthy animals. Schneider et al. (2009) demonstrated that the number of BRD related treatments an animal receives effects the animals' quality grade at slaughter. Schneider et al. (2009) reported that as the number of BRD related treatments increased (1, 2, ≥3) a lower percentage of the cattle graded choice or better (57, 55, 52% respectively) compared to cattle that had never been treated for BRD (71%). These results from Schneider et al. (2009) further support the results reported by Fulton et al. (2002) which found that calves that had been treated ≥ 2 times had lower quality grades compared to calves that had never been treated for BRD.

Strategies to mitigate BRD

Preconditioning

There are several management strategies employed in an attempt reduce the incidence and severity of BRD in beef cattle. One such strategy is the practice of preconditioning calves prior to sale and transportation. Some of the common components involved in preconditioning of calves include: vaccination for respiratory disease and clostridial diseases, weaning prior to sale, and training of calves to eat from bunk and drink from trough (Taylor et al., 2010). The goal of preconditioning is to reduce the amount of stress and prepare the calf for the transition into the feedlot. Taylor et al. (2010), reviewed the efficacy of several preventative measures used to combat BRD and concluded that the practice of preconditioning and vaccination have variable results. Ives and Richeson (2015) reported that preconditioned animals are better prepared for the transition from farm to feedlot, however, there is economic incentive to purchase high risk cattle at a reduced cost compared to purchasing preconditioned cattle due to the proven efficacy and availability of antimicrobial metaphylaxis.

Vaccination against BRD pathogens

Currently there are several strategies used in order to reduce or prevent the incidence of BRD in cattle, including but not limited to: the use of vaccines and the preconditioning calves prior to sale. The National Animal Health Monitoring System (NAHMS) reported that the practice of vaccination against BRD is used in 96% of feedlot cattle (NAHMS, 2013a). Commercially available vaccines are classified as either modified-live (MLV) or killed/inactivated (KV). Modified-live and KV vaccines both induce a humoral or antibody immune response, but MLV vaccines induce a more reliable cell mediated immune response compare to KV vaccines (Woolums et al., 2003; Ridpath, 2013). Fulton and Burge (2001) compared the antibody response to BVDV types 1 and 2 for MLV and KV vaccines, they found there was no difference in antibody response induced by either MLV or KV for type 1 BVDV. Studies have shown that MLV vaccinated animals are less susceptible to lymphocytopenia (Palomares et al., 2012; Downey-Slinker et al., 2016) and are better at preventing fever (Woolums et al., 2003; Palomares et al., 2012; Downey-Slinker et al., 2016) compared to non-vaccinated and KV vaccinated animals when exposed to BVDV or BHV-1. In a systematic review and meta-analysis of the current effectiveness of vaccines for BVD Theurer et al. (2015) reported that calves vaccinated with MLV had lower BRD morbidity and mortality risk and calves vaccinated with KV only had lower BRD risk morbidity compared to non-vaccinated calves. Schunicht et al. (2003) compared MLV multivalent viral vaccines to MLV univalent viral vaccines on animal health and feedlot performance, and found that multivalent vaccine treated calves had increased live and carcass weight and increased ADG compared to univalent viral vaccines. Schunicht et al. (2003) also found that there was an economic advantage of $0.74 Canadian dollars (CDN) per animal in the multivalent viral vaccine group compared to univalent vaccine group. This supports claims that MLV vaccines provide more robust and longer lasting protection against viral pathogens.

Vaccine type is not the only factor that affects the overall effectiveness to prevent illness; the time of vaccination, age and stress of an animal, and even administration route may also play a role in the overall effectiveness. Kirkpatrick et al. (2008) studied the effects of calf age at time of vaccination on antibody titers and feedlot performance. They found that the age of the calf did not affect the immunological response and that calves vaccinated at 67 d were able to generate antibodies to both BVD type 1 and BVD type 2. There was also no difference in feedlot performance based on age of vaccination (Kirkpatrick et al., 2008). Duff et al. (2000) used two studies to examine the effects of vaccine administration route and vaccine timing on health and performance of newly received calves. They found there was no difference between vaccinating on arrival or delaying 7 d but did see an increase in ADG in vaccinated calves compared to non-vaccinated. Chirase et al. (2001) examined the effect of clostridial vaccines given at different injection sites. In one experiment they found that steers given a clostridial vaccine injected subcutaneous prescapula had similar intake, ADG, increased bunk visits per d, increased eating time per d, and slower eating rate compared to control steers and steers vaccinated in the ear. This is evidence that injection site of vaccines impact behavior responses of cattle. Richeson et al. (2008) compared the effects of vaccinating with a MLV-vaccine on arrival or delayed (14 d) against infectious bovine rhinotracheitis (IBR) on the health and performance of newly received calves. They found that morbidity rates did not differ between vaccinating on arrival vs. delayed vaccination but found that animals that received the delayed vaccination had increased ADG and seroconversion to IBR. This suggests that allowing animal's time to adjust to their new surroundings and recover from previous stress, allows for better response to vaccination. Duff et al. (2000) also found that the vaccine administration route affects the performance in newly received calves. Calves that received the vaccine intramuscular had reduced ADG and increased F:G compared to calves that received the vaccine intranasal.

Temperament

Temperament can be defined as the fear response of cattle to human interaction. Cattle temperament can be assessed on a variety of scales and cattle that seem "wild" or more excitable to one person or within a certain group of cattle but may seem calm to another person or in a different group. Two main methods of evaluating cattle temperament are the assigning of a chute score and the use of exit velocity. Typically a 1 to 5 scale is used to evaluate the chute score on an animal (Grandin, 1993), with a score 1 being calm and a score of 5 being "wild" (rearing, twisting, or violently struggling). Chute scores are a subjective measure of how an animal reacts in a squeeze chute and must evaluated using trained personal. Exit velocity on the other hand utilizes a more objective measure to assign temperament to animals. The idea of using the animals velocity as it exits the chute as an objective way to assign temperament in cattle was first presented by Burrow et al. (1988). The thought behind the use of using exit velocity was that cattle with a more excitable temperament would exit the chute at a quicker rate compared to more calm temperament cattle (Burrow et al., 1988). To measure this velocity two sets of infrared sensors are placed in front of the chute at a known distance apart and the time is recorded from when the animal breaks the first sensor to when the animal passes the second sensor. The distance between sensors varies across studies but 1.8 m has been accepted as the de facto standard (Burrow et al., 1988; Curley et al., 2006; Nkrumah et al., 2007). Other subjective methods of temperament scoring such as pen scoring (Hammond et al., 1996; King et al., 2006) or approach-avoidance test (Murphey et al., 1981) have also been used to evaluate temperament in cattle.

Genetic influence of temperament

Substantial genetic differences have been documented in many cattle breeds and subsequent crosses. As a result, the distribution of temperament classification is typically confounded with sire, family, or breed. In many studies temperament classification may provide indirect identification of genetic influence. Zebu breeds of cattle have an establish reputation of having unfavorable temperaments (Cartwright, 1980) compared to British and Continental breeds. Previous research has shown that temperament of cattle is highly heritable (h = .49-0.61) in Angus sired steers (Gauly et al., 2001; Nkrumah et al., 2007). Similar heritability of temperament was shown in Nellore-Angus calves (Riley et al., 2014). This would suggest that by knowing the sire of a calf the temperament of the calf may be estimated.

Impact of temperament on feedlot performance

It has been well documented that calm cattle perform better compared to their more excitable counter parts. Previous research has shown that cattle temperament impacts the intake and performance of cattle such that, calm cattle tend to eat more feed and have increased ADG compared to excitable cattle (Burrow and Dillon, 1997; Voisinet et al., 1997; Petherick et al., 2002; Cafe et al., 2011; Bruno et al., 2016). In a study utilizing 120 *Bos indicus* crossed steers Petherick et al. (2002) reported that steers classified as having a poor temperament had lower ADG and feed conversion efficiencies compared to steers with good temperaments. Cafe et al. (2011) reported similar results that an increased flight speed during the background period was related to a decrease in DMI, less time spent eating, and lower ADG. Similar results were found when examining the flight speed during the feedlot phase, cattle with increased flight speed had lower ADG, less time spent eating, and tended to have lower DMI and lower feed conversion ratio compared to slower flight speed cattle. Bruno et al. (2016) reported that cattle with slower EV had increased ADG and DMI compared to cattle with faster EV but that there was effect of EV on G:F of receiving cattle.

The mechanisms associated with reductions in productivity of animals with excitable temperaments is not yet fully understood. However, it has been suggested that cattle with a more excitable temperament (i.e. faster EV) may tend to spend more energy being alert and nervous compared to the more calm counterparts (Burrow and Dillon, 1997; Petherick et al., 2002). Cattle with excitable temperament are more likely to spend a greater amount of time at elevated stress levels, thus having higher levels of blood cortisol (Fell et al., 1999; Curley et al., 2006). Animals with elevated serum cortisol concentrations may have increased mobilization of amino acids and fats from cellular stores shifting the energy partitioning away from growth and towards cellular maintenance and energy usage (Black et al., 1982).

Impact of temperament on feeding behavior

Due to the relative novelty of effective methods to monitor and measure feeding behavior in cattle, there is little available research regarding the association between cattle temperament and feeding behavior. One such study by Nkrumah et al. (2007) examined the effects of exit velocity (EV) on frequency and duration of feeding events, and head down duration in British-Continental crossbred steers. Despite a negative correlations between EV and DMI (Voisinet et al., 1997; Cafe et al., 2011; Bruno et al., 2016), Nkrumah et al. (2007) did not find an association between EV and the frequency and duration of feeding events, however they observed a weak negative correlation between head down duration and EV. Cafe et al. (2011) in addition to reduced DMI and ADG in excitable steers compared to calm steers, excitable steers spet less time at the feed bunk compared to calm steers.

Impact of temperament on immune health

Cattle with more excitable temperaments have been shown to have increased levels of circulating stress hormones, cortisol and epinephrine (Curley et al., 2006; Oliphint et al., 2006; Burdick et al., 2010). Cortisol is a hormone released in the body during times of stress and epinephrine is the hormone related to an animals fight or flight response. Burdick et al. (2009) examined the effects of temperament on immune responses in neonatal calves. Serum cortisol concentrations were not affected by temperament, however serum cortisol was positively correlated with exit velocity measured on d 21 to 24 after calving and with exit velocity measured at weaning. There was a negative correlation between cortisol and IgM and IgG_2, which are reflective of potential immunosuppressive effects of cortisol in neonatal calves (Burdick et al., 2009). Burdick et al. (2010) reported that temperamental bulls had increased cortisol and epinephrine compared to calm bulls before and after transport. In another study by Burdick et al. (2011a) they reported that cortisol levels in calm bulls increased due to stress of transport but were not changed in excitable bulls. The production of IgM by peripheral blood monocytes (PBMCs) was not affect by temperament or transportation, however IgM production was numerically greater prior to transport compared to post transport. Similarly, King et al. (2006) reported that excitable steers had 32.1% higher serum cortisol concentrations compared to calm steers. Increased cortisol levels have been shown to have a down-regulatory effect on the immune system causing decreased lymphocyte proliferation and antibody response to an antigen challenge in rats, along with a decrease in natural killer (NK) cell activity and decreased cytokine and reduction in cytokine receptor expression in rats (Solomon, 1969; Joasoo and McKenzie, 1976).

Cattle with excitable also appear to have a more compromised immune system compared to calm cattle when entering the feedlot (Fell et al., 1999; Oliphint et al., 2006; Burdick et al., 2011b). Hulbert et al. (2011) reported that calm temperament bulls had elevated neutrophil L-selectin expression, and phagocytic and oxidative burst activity compared to bulls with more excitable temperaments. (Oliphint et al., 2006) found that excitable cattle had reduced lymphocyte proliferation and had a reduced immune response to vaccination compared to calm calves. Fell et al. (1999) suggested that more excitable are more susceptible to disease compared to calm calves, with 5 of 12 excitable calves were pulled from their pen and 0 calm calves were pulled. Reinhardt et al. (2009) examined the effect of temperament with the risk of being treated for respiratory disease. They found that animals with a temperament score of 1 had a 27% chance of being treated and animals with a temperament score of > 3 had a 29% chance of being treated. Buczinski et al. (2015) found that temperament processing was significantly associated with odds of becoming morbid with BRD. Calves with a temperament score of 2 had 0.48 times greater odds of becoming morbid compared to calves with a temperament score of 1. Similarly, calves with a temperament score of 3 had 1.1 times greater chance of becoming morbid compared to calves with a temperament score of 1. However, when calves with temperament 1 or 3 were combined into a single group, stoic or very excitable cattle had a 2.2 times chance of being diagnosed with BRD compared to calves with a temperament score of 2.

Effects of morbidity on intake and feeding behavior

Intake and performance

It is well known that morbid animals do not perform as well as their healthy counterparts. Typically morbid animals have lower feed intake and subsequently lower ADG compared to healthy animals. Hutcheson and Cole (1986) reported that calves observed to be clinically ill had 11% lower intake and 29% lower ADG compared to calves observed to be healthy. Jackson et al. (2016) examined the deviations in DMI relative to the onset of BRD. Through the use of a 2 slope broken-line model, they found that DMI had a breakpoint 6.7 d prior to when clinical symptoms were observed and that DMI decreased by 39% from the detected breakpoint to the day clinical illness was detected. Carlos-Valdez et al. (2016) examined the effect of timing (early or late) of challenging steers with *Mannheimia hemolytica* (MH) following a short-term natural exposure to BVDV. They found that DMI, ADG, and G:F all decreased in the MH challenge steers from d 0 to 4 compared to control steers. However, from d 5 to 7 steers in the late MH challenge group appeared to compensate for the loss in production during d 0 to 4. In addition, Wolfger et al. (2015) reported that deviations in mean meal intake occurred 7 d prior to clinical detection and that increases in mean meal intake resulted in reduced risk for BRD.

Deviations in DMI have also been examined in dairy cattle relative to diseases and metabolic disorders. Dairy cows diagnosed with sub-clinical ketosis (SCK) showed a -3 kg decrease DMI compared to their healthy counter parts 1 week before they were diagnosed (Goldhawk et al., 2009). Similarly, cows diagnosed with clinical ketosis showed a 10 kg reduction in DMI compared to healthy cows several days before clinical diagnosis (González et al., 2008). Huzzey et al. (2007) reported cows with metritis had lower DMI compared to healthy animals prior to calving and suffered a greater decline post calving however DMI did increase in the days post calving. Knauer et al. (2017) examined the relationship between feeding behavior and morbidity in dairy calves. They found that morbid calves drank less compared to their healthy counterparts.

Changes in feeding behavior due to morbidity

Feeding behavior of cattle can be influenced by a number of factors, including environment, temperament, and animal health. The development and availability of remote monitoring systems allows for feeding behaviors such as, frequency and duration of feeding events, to be quantified and compared across numerous production settings including disease challenges. Sowell et al. (1998) reported that morbid steers had reduced feed intake by 11% and spent 30% less time at the feedbunk compared to healthy animals. Buhman et al. (2000) examined the changes in eating behavior of newly received feedlot calves. Sick calves were found to have lower eating frequency and duration 11 to 27 d post arrival at the feedlot compared to their healthy counterparts. In another study, Sowell et al. (1999) examined the feeding behavior between healthy and morbid steers in two trials. In the first trial healthy steers spent more time at the feedbunk and had more feeding bouts compared to morbid steers. However in the second trial there was no difference between healthy and morbid steers in terms of time spent at the feedbunk but health steers did have more feeding bouts compared to morbid steers. Wolfger et al. (2015) examined the use of changes in feeding behavior as an early predictor of BRD. They reported that both mean meal time and meal frequency were both indicators of morbidity between 5 and 1 d prior to visual detection. They also found that for every 1 min increase in feeding time per meal the hazard for BRD decreased 13-17% and as meal frequency increased by 1 meal per day resulted in BRD hazard reduced by 16-21% (Wolfger et al., 2015).

Changes in feeding behavior have also been examined in dairy cattle with both metabolic and reproductive disorders. Goldhawk et al. (2009) examined the changes in feed intake and behavior of dairy cattle in the transition period as an indicator for subclinical ketosis (SCK). They found that cows with SCK had lower DMI, 18-20%, compared to healthy cows and that cows diagnosed with SCK spent less time, 16-28%, at the feedbunk than the healthy cows. Urton et al. (2005) examined the feeding behavior of dairy cows at risk for metritis 2 weeks prior to calving and for 3 weeks post calving. Cows that showed signs of metritis spent an average of 22 min/d less time at the feed alley compared to the cows that did not show any signs. This decline in time at the feed alley was shown to be a useful tool in identifying cows at the most risk for metritis, because for every 10 min reduction in feeding time the likelihood of the being diagnosed with metritis doubled (Urton et al., 2005).

There have been several studies looking at the feeding behavior of healthy animals compared to morbid animals, however there needs to be further research into economics associated with the technologies used to collect the data. One such technology often used in collecting this kind of data is the GrowSafe system (Airdrie, AB, Canada), which allows for the collection of individual intake and feeding behaviors.

The system continuously records weights entering and leaving the feedbunk. However, one problem with data collection system like GrowSafe, is the initial input cost for the equipment, since each bunk needs to be equipped with load bars to weigh the bunks. For this reason there has been interest in developing an active RFID system as a cost effective method to monitor feeding behavior. White et al. (2015) examined the use of a Remote Early Detection Disease Identification (REDI) system compared to visual observations for disease detection. Eighty bull calves were assigned to one or two groups, REDI or visual observation. They found that both methods had high a probability of making the correct call, but that the use of the REDI system was able to identify sick cattle on average 18 h before visual observations were made.

Summary

Although BRD is one of the most widely documented and studied disease complexes in the cattle industry, little progress has been made reducing the incidence of this disease. The lack of progress in the reducing the incidence of BRD, may be attributed to the numerous pathogens involved with BRD and outdated disease detection methods. Additionally, the potential interaction between pathogens can further impair immune function and adds a level of complexity to the prevention of BRD. Current detection methods rely on subjective measures to determine morbid animals; current technology allows for more objective measures of detection with proven increased accuracies. However, the economic cost related to some of these technologies (i.e. remote monitoring systems) has prevented there implementation into commercial feed yards. While vaccination is a common practice upon entry in the feed yards it does not have the same benefit as vaccination prior to sale via a preconditioning program. Vaccine type (MLV vs. KV) can influence overall effectiveness and level of protection gained from vaccination. Studies have shown that MLV vaccines tend to provide better protection compared to KV vaccines. Changes in cattle feed intake and feeding behavior have been shown to be some of the first signs of morbidity prior to clinical symptoms. Using this information evaluating vaccines based on deviations in feed intake and feeding behaviors, in addition to antibody response, may provide a clearer picture as to the effectiveness of the vaccine.

CHAPTER II

EFFECTS OF VACCINE TREATMENT AND TEMPERAMENT ON FEED INTAKE, PERFORMANCE, AND FEEDING BEHAVIOR RESPOSNES TO BVD VIRAL CHALLENGE IN BEEF STEERS

Introduction

Bovine respiratory disease (BRD) remains one of the most costly and prevalent diseases present in the cattle industry (Griffin, 1997; Smith, 1998), despite the fact that multivalent vaccines for the prevention of BRD are widely used in feedlot cattle (96% of feedlots; NAHMS, 2013a). Efficacy of multivalent BRD vaccines has been shown to be impacted by a number of factors including stressors associated with weaning, commingling and transportation (Smith, 2004; Richeson et al., 2009), and animal temperament (Oliphint et al., 2006) which can affect the immunocompetence of the animal.

Type of vaccine has also been shown to impact the degree of protection against BRD. In general, modified-live (MLV) vaccines have been shown to elicit a more robust and longer lasting immune responses (Ridpath et al., 2010; Ridpath, 2013) compared to killed vaccines (KV). Theurer et al. (2015) reported that the administration of multivalent MLV vaccines has been shown to reduce BRD morbidity compared to multivalent KV vaccines. Additionally, Stevens et al. (2011) demonstrated that calves vaccinated with a MLV vaccine had lower mortality rates compared to non-vaccinated calves.

Cattle temperament can impact the immunocompetence of the animal, with more excitable cattle having compromised immune function compared to calm cattle. Oliphint et al. (2006) found that excitable steers had lower *in vivo* lymphocyte proliferation and lower *in vivo* vaccine-specific IgG concentrations compared to steers with calm temperaments. This suggests that calm animals would have a greater level of protection from vaccination compared to excitable animals.

There has been limited research examining the effect of vaccination on feed intake, performance and feeding behavior responses in cattle following a disease challenge. Similarly, there is limited research available examining the interaction of temperament and vaccination on feed intake, performance, and feeding behavior responses. For these reasons, the objectives of this study were to examine the effects of multi-viral vaccine treatment and temperament on feed intake, performance, and feeding behavior responses to a bovine viral diarrhea (BVD) viral challenge.

Materials and Methods

Animal and experimental design

All animal procedures were reviewed and approved by the Texas A&M University Institutional Animal Care and Use Committee (AUP# 2010-080 and 2013-0069) as well as the Texas A&M University Institutional Biosafety Committee.

The animals utilized in this study were half-blood (F_2 and F_3) Angus-Nellore steers (N = 360) from the Texas A&M University McGregor Genomics herd, which consist of a *Bos taurus-Bos indicus* crossbred population that was specifically developed to support genomic studies. Four trials were conducted during consecutive years from 2010 to 2013. The steers were born in the spring, and were not previously vaccinated against BRD pathogens. Steers were weaned at approximately 7 months of age and received 3 clostridial vaccinations with Closti Shield 7 (Novartis Animal Health US, Inc., Greensbro, NC) at approximately 70 days of age, 3 weeks prior to weaning, and at weaning. Following weaning, calves were managed as single groups and remained on pasture or were fed a growing ration depending on the year until being transported 165 km from McGregor to College Station in January or February. Steers were confirmed to be BVDV-PI negative through evaluation of ear notch samples by antigen capture ELISA, and were seronegative for BVDV antibodies (Texas Veterinary Medical Diagnostic Laboratory; TVMDL, Amarillo, TX). Throughout this study, low-stress cattle handling methods were emphasized during movement, processing, and data collection.

Cattle were housed at the Texas A&M University Beef Systems Research Unit (College Station, Texas) in 1 of 4 pens, each equipped with 4 electronic feed bunks

(GrowSafe System LTD., Airdrie, AB, Canada) with approximately 20 to 26 steers per pen. A high-forage growing diet was used in this study that consisted of approximately 31.5% corn, 36.5% chopped alfalfa, 24.5% dry distillers grains, 2.5% commercial premix, and 5% molasses. The ration was formulated to meet nutrient requirements for growing steers (NRC, 2000). Feed was delivered twice daily to ensure *ab libitum* access throughout the trials. Cattle were acclimated to the diet for 4 to 8 weeks prior to the start of the trials.

Vaccination and challenge protocols

At approximately 12 mo of age, steers were stratified by sire and genomic cow families, and randomly assigned to 1 of 3 vaccine treatments (**VT**) that consisted of killed virus (**KV**) vaccine, modified-live virus (**MLV**) vaccine, and no vaccine (**NON**). Both vaccines were labeled for protection against infectious bovine rhinotracheitis, parainfluenza-3, bovine respiratory syncytial virus, and BVD virus and were used according to label directions. Steers assigned to the KV treatment received an initial vaccine dose (Vira-shield®; Novartis Animal Health US, Inc.) -56 or -49 d prior to BVD viral challenge and a second dose administered 21 d later. Steers assigned to the MLV treatment were vaccinated with a single dose of Arsenal 4.1® (Novartis Animal Health US, Inc.) on the same d that the second KV dose was administered. The NON-vaccinated steers received neither vaccine nor a sham injection prior to BVD viral challenge. The MLV-vaccinated steers were isolated from KV- and NON-vaccinated steers for 7 to 10 d following vaccination to avoid nose-to-nose contact.

All steers were challenged with the type 1b non-cytopathic BVDV strain (CA0401186a) that was obtained from the USDA-ARS National Animal Disease Center, Ames, IA. This BVDV strain, originally isolated from a persistently infected BVDV calf, was selected for use in this study because it had previously been shown to cause recognized immunological and clinical signs of morbidity, but with minimal risks of extreme illness or death (Ridpath et al., 2007). Each steer was administered 5 mL of BVDV inoculum containing 1×10^5 TCID/mL intranasally (2.5 mL dose per nasal passage). Challenge dates (d 0) were May 11, May 10, May 15, and June 4 for trial years 2010-2013, respectively.

Sample and data collection

Body weight (**BW**), exit velocity (**EV**), and rectal temperature were measured on d -28, 0, 3, 7, 10, 14, 28, and 42 relative to BVD challenge (d 0). Exit velocity was measured as the velocity (m/s) as animals travelled at over a fixed distance of 1.8 m upon exiting the squeeze chute using infrared sensors (Farm Tec, Inc. North Wylie, TX). Relative exit velocity (**REV**) was computed as (individual EV – mean EV) ÷ mean EV for each animal within year, and the average REV for d 0 and 14 defined as initial REV. Dry matter intake, ADG, and feeding behavior traits were evaluated during 4 14-d experimental periods (**EP**) relative to BVD challenge on d 0: Period 1 (d -14 to 0), Period 2 (d 1 to 14), Period 3 (d 15 to 28), and Period 4 (d 29 to 42). The ADG during the first 14-d period was calculated using the BW from d -28 and the BW on d 0.

The steers were observed twice daily during the first 14 d following the BVD viral challenge, and once daily thereafter to assess clinical symptoms of BRD. Clinical evaluations of multiple symptoms including cough, ocular and nasal secretion, depression, diarrhea, and anorexia were recorded using a 0 to 5 clinical illness score (**CIS**; 0 = no symptoms; 1 to 5 indicative of least severe to most severe). The criterion used to define BRD cases in this study were clinical scores of > 3 for a single clinical symptom or combined scores of ≥ 3 for 2 or more clinical symptoms. Rectal temperatures were recorded on pre-determined days rather than as a final clinical threshold following initial clinical assessment, as would be the case in a field protocol for BRD diagnosis (Downey-Slinker et al., 2016). Animals that exhibited a rectal temperature > 40^{o} C were administered *tulathromycin* (Draxxin, Zoetis Animal Health), regardless of clinical illness scores. The effects of sire, rectal temperature, and presence of clinical signs following a BVD viral challenge were previously presented (Runyan, 2013; Downey-Slinker et al., 2016).

GrowSafe data

A GrowSafe system (DAQ 6000E) was used to measure feed intake and feeding behavior traits from -14 d prior to 42 d following the BVD viral challenge. The system consisted of feed bunks equipped with load bars to measure feed disappearance and RFID antennas within each feed bunk to record animal presence via detection of EID ear tags. Assigned feed disappearance (**AFD**) rates were computed daily for each feed bunk to assess data quality. Data for each pen were omitted from analysis due to system malfunction, power outage, or low (< 95%) pen-average AFD rates. During the 2010 and 2013 trials, data for 14d and 2 d, respectively, were removed due to low AFD rates. The average AFD for the remaining days were 97.1% and 99.3%, respectively. No data were removed from the 2011 and 2012 trials, with average AFD rates exceeding 99%. Feeding behavior traits evaluated in this study were based on frequency and duration of bunk visit (**BV)** events, head down (**HD**) duration, frequency and duration of meals events, and time to approach feed bunk following feed-truck delivery (**TTB**; Table 1). A BV event commenced when the EID ear tag of an animal was first detected at the feed bunk and ended when the time between the last 2 consecutive EID recordings exceeded 100 s, the EID ear tag was detected at another feed bunk, or the EID ear tag of another animal was detected at the same feed bunk (Mendes et al., 2011). Bunk visit frequency was defined as the number of independent events recorded regardless of whether or not feed was consumed, and BV duration was defined as the sum lengths of all BV events recorded during a 24-h period (Jackson et al., 2016). Head down duration was computed as the sum of the number of times an EID ear tag was detected each day multiplied by the scan rate of the GrowSafe system. The R statistical software (R Core Team, 2014), was used to compute TTB each day as the interval length between feed delivery for each pen and each animal's first BV event following feed delivery (Jackson et al., 2016). Estimated values for missing feed intake data were derived from linear regression of the feed intake on the day of the trial (Hebart et al., 2004). Bunk visit eating rate was computed as the ratio of daily DMI to daily BV duration.

To compute meal data, a 2-pool Gaussian-Weibull distribution model was fitted to log-transformed non-feeding interval data. The intercept of the 2 distributions were used to define meal criterion (Yeates et al., 2001; Bailey et al., 2012), which is the longest non-feeding interval considered to part of a meal event. Individual-animal meal criterion was used to compute frequency and duration of daily meal events. Meal eating rate was computed as the ratio of daily DMI and daily meal duration.

Statistical analysis

Mixed model procedures of SAS 9.4 (SAS Inst. Inc., Cary, NC) were used to analyze DMI, ADG, and feeding behavior data. The model included vaccine treatment and experimental period as fixed effects, initial REV as a covariate, and the interactions of VT x EP, VT x initial REV, EP x initial REV and VT x EP x initial REV, and the random effects of year and pen within year. The 3-way and the EP x initial REV interactions were non-significant for all dependent variables and so were removed from the final models. Contrast statements were used to examine responses of dependent variables (linear, quadratic, or cubic) across EP. Least squares differences among vaccine treatments and experimental period means were evaluated using the pdiff option of SAS.

To examine the distribution of temperament across vaccine treatments, temperament was classified categorically (mean initial REV ± 0.5 SD). The distribution of temperament classification within vaccine treatments were examined using PROC FREQ (SAS 9.4). To examine the possible interactive effects of vaccine treatment and initial REV an unequal slope model was fitted. For dependent variables with a significant VT x initial REV interactions ($P < 0.05$), vaccine treatment subclass means were compared at mean initial REV minus 1 SD and mean initial REV plus 1 SD to represent calm and excitable cattle, respectively, using pdiff option of SAS.

Results

During the 14-d period following the BVD viral challenge, 14% of the steers had CIS of 1 or 2. However, none of the steers met the criteria for clinical BRD diagnosis (> 3 for single clinical symptom; ≥ 3 for combined scores of 2 or more clinical symptoms), and none of the steers died during the study. In response to the BVD viral challenge, 40% of steers presented with pyrexia, which for this study was defined as an elevated rectal temperature of 1 SD greater than the baseline temperature (day 0) for 2 or more consecutive measurement days within the 14-d period following BVD viral challenge period (Downey-Slinker et al., 2016). Additionally, 55% of steers presented with lymphopenia (> 40% reduction in lymphocyte counts), and 41% with thrombocytopenia (> 40% reduction in platelet counts) during the 14-d period following BVD challenge (Downey-Slinker et al., 2016).

Vaccine treatment and experimental period

The least square means for DMI, performance, and feeding behavior responses are presented in Table 3. Compared to period 1, DMI, ADG, and G:F were reduced 15.9, 27.7, and 20.0%, respectively, during the 14-d period following BVD viral challenge (period 2), and subsequently increased during periods 3 and 4 in a cubic ($P < 0.01$) manner. Although vaccine treatment did not affect DMI, ADG, or G:F, there was a VT x EP interaction ($P < 0.05$, Fig. 1) for DMI. The reduction in DMI during period 2 following BVD viral challenge was less ($P < 0.05$) for MLV steers (-10.6%) compared to KV (-18.2%) and NON steers (-18.9%), and correspondingly, the subsequent increase in DMI during period 3 was greater for KV- and NON-vaccinated steers compared to

MLV-vaccinated steers. While the VT x EP interaction was not significant ($P = 0.11$) for ADG, the reduction in ADG during period 2 was numerically less for MLV (14%), compared to KV- (37%) and NON-vaccinated (33%) steers (Fig. 1).

Compared to period 1, frequency and duration of BV events, frequency and duration of meal events, HD duration, and BVM all decreased 24.6, 15.3, 15.1, 21.5, 17.2, and 13.1%, respectively, during period 2 and subsequently increased during period 3 in a cubic ($P < 0.01$) manner. In contrast to these feeding behavior traits, meal eating rate actually increased 6.4% during the 14-d post BVD viral challenge (period 2) and continued to increase during period 4 in a cubic ($P < 0.01$) manner. In contrast with meal eating rate, BV eating rate was not affected by BVD viral challenge. During the 14-d post BVD viral challenge, time to approach the feed bunk following feed delivery was increased by 37.1%. During periods 3 and 4, TTB were similar to values recorded prior to the BVD viral challenge.

In contrast with DMI, there were no significant VT x EP interactions detected for any of the feeding behavior traits. However, with the exception of BV frequency and TTB, vaccine treatment significantly altered feeding behavior traits throughout the study (Table 2), with MLV-vaccinated steers having distinctly different feeding behavior patterns compared to KV- and NON-vaccinated steers. The MLV-vaccinated steers had 5 to 7% greater ($P < 0.01$) HD duration and durations of BV and meal events, and 4 to 5% slower ($P < 0.01$) BV and meal eating rates compared to KV- and NON-vaccinated steers. Additionally, MLV steers had 4 to 6% greater ($P < 0.01$) number of BV events per meal compared to KV- and NON-vaccinated steers. The time to approach the feed bunk following feed delivery and BV frequency were not affected by vaccine treatment.

Temperament

Temperament was assessed post trial in a retrospective analysis. Frequency of temperament classification across vaccine treatments are provided in Table 2. The distribution of temperament classification indicated that KV- and MLV-vaccinated steers had a greater proportion of steers classified as excitable compared to NON-vaccinated steers. Additionally, NON-vaccinated steers had a greater proportion of steers classified as calm compared to KV- and MLV-vaccinated steers.

Initial REV was a significant covariate ($P < 0.01$) for DMI, such that steers with calm temperaments (mean initial REV – 1 SD) consumed 5.0% more feed than steers with excitable temperaments (mean initial REV + 1 SD), irrespective of vaccine treatment (Table 3). There was a tendency ($P = 0.08$) for initial REV to affect ADG, with calm steers having numerically 5.3% higher ADG compared to excitable steers. However, initial REV did not affect ($P = 0.69$) G:F, and VT x initial REV interactions were not detected for DMI, ADG, or G:F ($P \geq 0.25$).

With the exception of BV frequency, initial REV was a significant covariate for all feeding behavior traits. In general, HD duration, and BV and meal duration all decreased ($P < 0.01$) as initial REV increased (Table 4). However, VT x REV interactions were detected (P < 0.05) for both HD and meal duration. In KV- and NON-vaccinated steers, these traits were not affected by initial REV, but in MLV-vaccinated steers, both HD and meal duration decreased as initial REV increased. Within calm steers, MLV-vaccinated steers had increased (*P* < 0.01) HD and meal duration compared to KV- and NON-vaccinated steers. However, within excitable steers, differences between vaccine treatments were not detected for HD and meal duration (Figure 2). There were significant VT x initial REV interactions for both BV and meal eating rates. Bunk visit eating rate increased as initial REV increased in both MLV- and NON-vaccinated steers, but not in KV-vaccinated steers. Additionally, meal eating rate increased as initial REV increased in MLV-vaccinated steers, but not in KV- and NON-vaccinated steers (Figure 2).

Although frequency of BV events was not affected by initial REV, there was a VT x initial REV interaction for frequency of meal events. Meal frequency increased as initial REV increased in KV- and NON-vaccinated steers, however, initial REV had no effect on meal frequency in MLV-vaccinated steers. Within the excitable steers, KV- and NON-vaccinated steers had more meals per day then MLV-vaccinated steers, whereas, in calm steers vaccine treatment did not affect meal frequency (Figure 3). Reflecting the influence that temperament had on meal frequency, the number of BV events per meal declined as initial EV increased. Time to bunk following feed delivery was affected by initial REV, irrespective of vaccine treatment, with excitable steers taking about 4 min longer to approach the feed bunk than calm steers (Table 3).

Discussion

Following an intranasal challenge with type 1b non-cytopathic BVD viral strain none of the steers were diagnosed with clinical BRD, and only 14% of the steers exhibited mild clinical symptoms (CIS ≤ 2) of BRD. However, 55% of steers presented with lymphopenia and 41% with thrombocytopenia, which are both well-established subclinical indicators of BVD infection (Stevens et al., 2011; Palomares et al., 2012; Downey-Slinker et al., 2016). Other studies have also shown that animals challenged with BVDV type 1b (Ridpath, 2013) or BVDV type 2 (Kelling et al., 2007) strains do not always manifest with observed clinical symptoms of BRD. Burciaga-Robles et al. (2010) reported that calves exposed to BVDV type 1b had minimal to no observed clinical symptoms. Several studies have observed declines in lymphocyte counts following BVD viral challenge (Palomares et al., 2012; Downey-Slinker et al., 2016).

Despite the lack of clinically diagnosed BRD cases, there were substantial reductions observed in DMI, ADG, G:F, and feeding behavior traits following the BVD viral challenge. During a spontaneous outbreak of BRD in growing bulls (8-9 mo), Jackson et al. (2016) reported that DMI was reduced by 39% during the week prior to observed clinical BRD diagnosis. Likewise, frequency and duration of BV events declined by 2.9 events/d and 4.4 min/d, respectively, during the week prior to observed clinical diagnosis of BRD. Carlos-Valdez et al. (2016) reported that Angus crossbred steers challenged with *Mannheimia haemolytica* after exposure to a persistently infected BVDV type 1 calf had reduced DMI, ADG, and G:F during the first 4 d following challenge. Similarly, Theurer et al. (2013) reported that calves challenged with *M.*

haemolytica spent less time at the feed bunk and hay feeder compared to calves that were not challenged. In addition, Wolfger et al. (2015) reported that an increase in feed intake per meal event along with increases in frequency and duration of meal events were associated with lower risk for developing BRD. Hutcheson and Cole (1986) reported that calves observed to be clinically ill had 11% lower intake and 29% lower ADG compared to calves observed to be healthy. Sowell et al. (1999) examined the differences in feeding behavior between healthy and morbid mixed breed steers. They found that morbid steers had fewer feeding bouts and spent less time at the feed bunk compared to healthy steers. Furthermore, Sowell et al. (1998) reported healthy mixed breed steer had a more rapid response to feed delivery compared to morbid steers. Daniels et al. (2000) reported that calves identified as morbid had fewer feeding bouts and spent less time at the feed bunk compared to healthy calves.

Similar reductions in DMI and feeding behavior responses prior to diagnosis of mastitis (Lukas et al., 2008), metritis (Urton et al., 2005), ketosis (González et al., 2008), and subclinical ketosis (Goldhawk et al., 2009) have been reported in dairy cows. Cows with mastitis have been shown to have lower DMI compared to healthy cows (Lukas et al., 2008). Cows diagnosed with metritis have been shown to spend an average of 22 min/d less at the feed bunk during the transition period compared to healthy cows (Urton et al., 2005). González et al. (2008) reported that cows with ketosis were categorized by a decrease in feed intake, feeding time, and feeding rate an average of 3.6 d prior to diagnosis by farm staff. Goldhawk et al. (2009) found that during the week prior to calving and the two weeks following calving, cows with subclinical ketosis had lower

DMI and spent less time at the feed bunk compared to healthy cows. Additionally, the risk for subclinical ketosis increased by 1.9 times for every 10-min decrease in time spent at the feed bunk the week before calving, and the risk for subclinical ketosis increased by 2.2 times for every 1 kg decrease in DMI.

Following the decline in DMI, ADG, G:F, and feeding behavior responses there were subsequent increases in DMI, ADG, G:F, and feeding behavior responses during periods 3 and 4. Buhman et al. (2000) reported that morbid calves had fewer feeding bouts and spent less time at the feed bunk 11 to 27 d after arrival compared to healthy calves, however, during 28 to 57 d post arrival morbid calves had increased frequency of feeding bouts and numerically greater duration compared to healthy calves. Buhman et al. (2000) attributed this increase in feeding bouts and duration at the feed bunk to a post-sickness compensation. Carlos-Valdez et al. (2016) found that after the decline in DMI, ADG, and G:F during d 0 to 4 post challenge compared to control calves, there was a subsequent increase in ADG and G:F during d 5 to 17. Calves challenged with *M. haemolytica* during d 5 to 17, appeared to compensate for the loss in production and showed an increase in ADG and G:F compared to control calves. Holland et al. (2010) reported that crossbred heifers that had been treated for BRD had lower ADG compared to cattle that had not been treated during the preconditioning phase. Additionally, there was a greater compensation in ADG during the first 28 d following the preconditioning phase for cattle treated 3x compared to cattle that had never been treated. A similar compensation was observed for ADG, G:F, and frequency and duration of feeding events in the current study during period 3 following BVD viral challenge.

Results of the current study showed that DMI, ADG, G:F, frequency and duration of both BV and meal events all decreased following BVD viral challenge and increased again during period 3. However, the decline in DMI following BVD viral challenge was less for MLV-vaccinated steers compared to both KV- and NON-vaccinated steers. These results support previous findings reported in a companion study (Downey-Slinker et al., 2016) demonstrating that MLV-vaccinated steers had reduced (33.9%) incidence of lymphopenia compared to KV- (64.7%) and NON-vaccinated steers (68.1%). Likewise, the incidence of thrombocytopenia during the 14-d post BVD challenge period was less for MLV-vaccinated (31.5%) and KV-vaccinated steers (37.8%) compared to NON-vaccinated steers (53.5%). Although vaccine treatment did not affect the proportion of steers that exhibited pyrexia during the 14-d post BVD challenge period, MLV-vaccinated steers had lower rectal temperature compared to KV- and NON-vaccinated steers on days 3 and 7 post challenge. Vaccine treatment clearly altered feeding behavior patterns, such that MLV-vaccinated steers had greater duration of both BV and meal events, greater HD duration, and slower eating rates compared to KV- and NON-vaccinated steers. These results, in conjunction with Downey-Slinker et al. (2016), suggested that the MLV multivalent vaccine provided a greater level of protection to the BVD viral challenge compared to the KV vaccine. Although some studies have reported no difference in antibody response between KV and MLV vaccines (Fulton and Burge, 2001), Downey-Slinker et al. (2016) found that MLV-vaccinated steers had greater BVD type 1b titer concentrations compared to KV-vaccinated steers prior to BVD viral challenge. Additionally, MLV vaccines have been shown to reduce susceptibility to lymphopenia and reduce fever response to a greater extent as compared to KV vaccines (Woolums et al., 2003; Palomares et al., 2012). This would suggest that the MLV vaccine was more effective at mitigating subclinical symptoms of BRD compared to a KV vaccine.

The effects of temperament on DMI and performance of cattle in multiple breeds have been well documented, such that more excitable steers have decreased DMI and ADG compared to calm steers (Elzo et al., 2009; Cafe et al., 2011; Bruno et al., 2016). In agreement with previous research, results of the current study found that calm steers had greater DMI and numerically greater ADG compared to excitable steers. However, there have been mixed results on the effect of temperament on feed efficiency. Bruno et al. (2016) reported that temperament did not affect G:F even though cattle with calm temperaments had increased DMI and ADG compared to excitable cattle. Petherick et al. (2002) found that *Bos indicus* crossbred steers with excitable temperaments had lower ADG and less favorable G:F compared to steers with calm temperaments. Likewise, Cafe et al. (2011) reported that Angus steers with excitable temperament based on EV at feedlot arrival tended to have less favorable G:F then steers with excitable temperaments. The results of the current study are contrary to those found by Petherick et al. (2002) and Cafe et al. (2011) and support those found by Bruno et al. (2016) that there was no effect of temperament on G:F. In the current study, temperament also altered feeding behavior responses such that duration of both BV and meal events decreased as REV increased and the frequency of feeding events and BV eating rate increased as REV increased. Nkrumah et al. (2007) reported that although there was a negative phenotypic relationship between DMI and exit velocity, there was not a phenotypic relationship between feeding frequency and duration and exit velocity but found a weak negative relationship with HD duration in British x Continental crossbred steers. However, Cafe et al. (2011) reported that cattle with faster EV spend less time at the feed bunk compared to cattle with slower EV. Results of the current study support those found by Cafe et al. (2011), such that more excitable steers had lower feeding duration compared to calm steers.

The distribution of temperament classification was not independent of vaccine treatment such that, MLV- and KV-vaccinated steers had a greater proportion classified as excitable and a lower proportion classified as calm compared to NON-vaccinated steers. However, differences in vaccine treatment were observed such that, MLV-vaccinated steers had increased BV, HD, and meal duration and slower BV and meal eating rates compared to KV- and NON-vaccinated steers within calm steers. With the exception of meal frequency, these differences were not observed in excitable steers. These differences between vaccine treatments were not observed in the excitable steers which may be related to the increased stress responsiveness of excitable steers. Excitable steers have been shown to have an increased responsiveness to stress, such as increased levels of circulating cortisol compared to calm steers (Curley et al., 2006), which had been shown to have a negative effect on immunocompetence (Burdick et al., 2009). In addition Oliphint et al. (2006) reported that cattle with excitable temperaments had a reduced immune response to vaccination compared to calm cattle. In the current study the beneficial effects of the MLV vaccine appear to be mitigated by the increased stress responsiveness in excitable cattle. Additionally excitable steers may not have mounted a full immune response to the MLV vaccine preventing the animals from developing a similar level of protection compared to the calm steers.

Conclusion

In conclusion, the results of the current study demonstrated that vaccine treatment clearly altered DMI following BVD viral challenge, such that MLV-vaccinated steers had less of a reduction in DMI compared to KV- and NON-vaccinated steers. Feeding behavior was affected by vaccine treatment, with MLV-vaccinated steers having increased feeding duration and slower eating rates compared to KV- and NON-vaccinated steers. These results in conjunction with the results of a companion study (Downey-Slinker et al., 2016) suggest that the MLV vaccine mitigated the negative effects of the BVD viral challenge to a greater extent compared to KV and NON vaccines. Additionally, temperament affected DMI and feeding behavior responses with calm steers having increased DMI and feeding duration and slower eating rates compared to excitable steers. Previous analyses in these cattle have demonstrated substantial genetic influence for temperament at weaning (Riley et al., 2014) and DMI and ADG following BVDV challenge (Runyan, 2013), however because there is a large degree of confounding between sire and temperament, only temperament classification was used for this study. Additionally, the increased stress responsiveness of excitable steers appears to have mitigated the beneficial effects of the MLV vaccine. Since deviations in DMI and feeding behavior responses occur prior to clinical symptoms (Goldhawk et al., 2009; Jackson et al., 2016), utilization of these deviations with respect to vaccination may provide a clearer picture into overall vaccine efficacy and protection to disease.

CHAPTER III

SUMMARY

Currently BRD remains one of the most costly and prevalent diseases present in the cattle industry (Griffin, 1997; Smith, 1998). With public perception shifting towards minimizing the use of antibiotics in cattle due to fear of antibiotic resistant bacteria. The use of preventative measures such as preconditioning and vaccination are coming to the forefront as a major factor in preventing BRD. However, vaccine efficacy is affected by several factors including vaccine type and cattle temperament. The use of MLV vaccines have been shown to provide a more robust and greater level of protection compared to a KV vaccines (Ridpath, 2013; Theurer et al., 2015). Additionally, calm-temperament cattle have been shown to have a greater immune response to vaccination compared to excitable-temperament cattle (Oliphint, 2006).

The current study found that vaccine treatment clearly altered DMI, ADG, and feeding behavior responses relative to BVD viral challenge. Steers that received a MLV vaccine had greater DMI and numerically higher ADG compared to KV- and NON-vaccinated steers following BVD challenge. Feeding behavior patterns were clearly altered in MLV-vaccinated steers compared to KV- and NON-vaccinated steers. Calm cattle had more favorable DMI and ADG compared to excitable cattle, but there was no effect on G:F ratios. Furthermore, temperament had an effect on feeding behavior patterns, which are correlated with DMI and ADG in cattle, such that calm cattle spent longer at the feed bunk compare to excitable steers. Effects of vaccine treatment were more pronounced in calm steers compared to excitable steers. Results from the current study in conjunction with Downey-Slinker et al. (2016) demonstrates that MLV vaccine provided a greater level of protection compared to the KV vaccine. Additional research is warranted to further examine the interactive effects of vaccine treatment and temperament on physiological, immunological, and behavioral responses to disease challenge in beef cattle.

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APPENDIX A

FIGURES

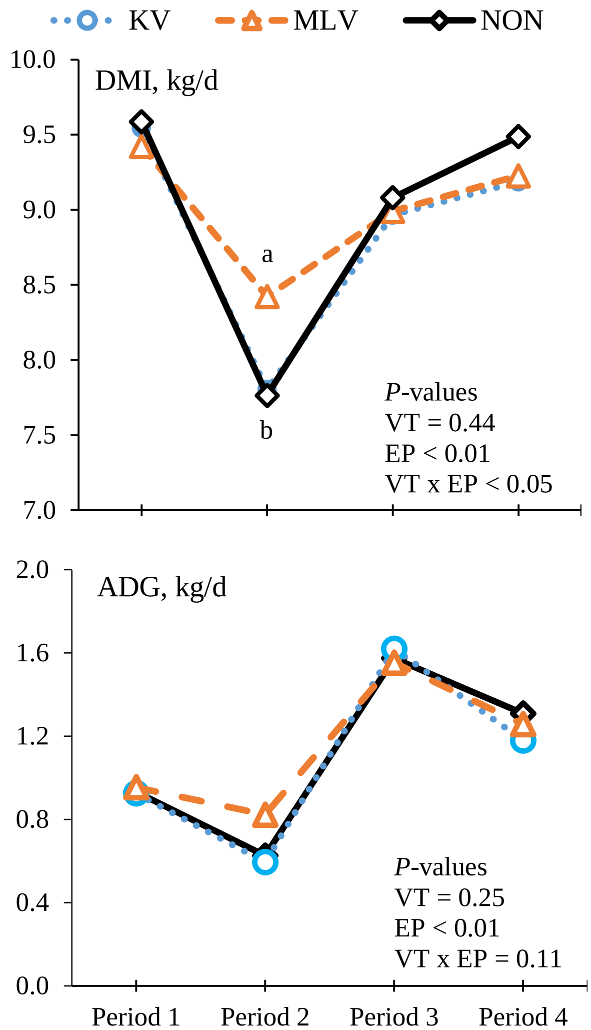

Figure 1. Effects of vaccine treatment and experimental period on DMI and ADG. [a,b]Indicates DMI difference ($P < 0.05$) within sub class means, showing MLV different from NON and KV steers. Periods correspond to 14-d intervals before (Period 1) and immediately following (Periods 2-4) BVDV challenge.

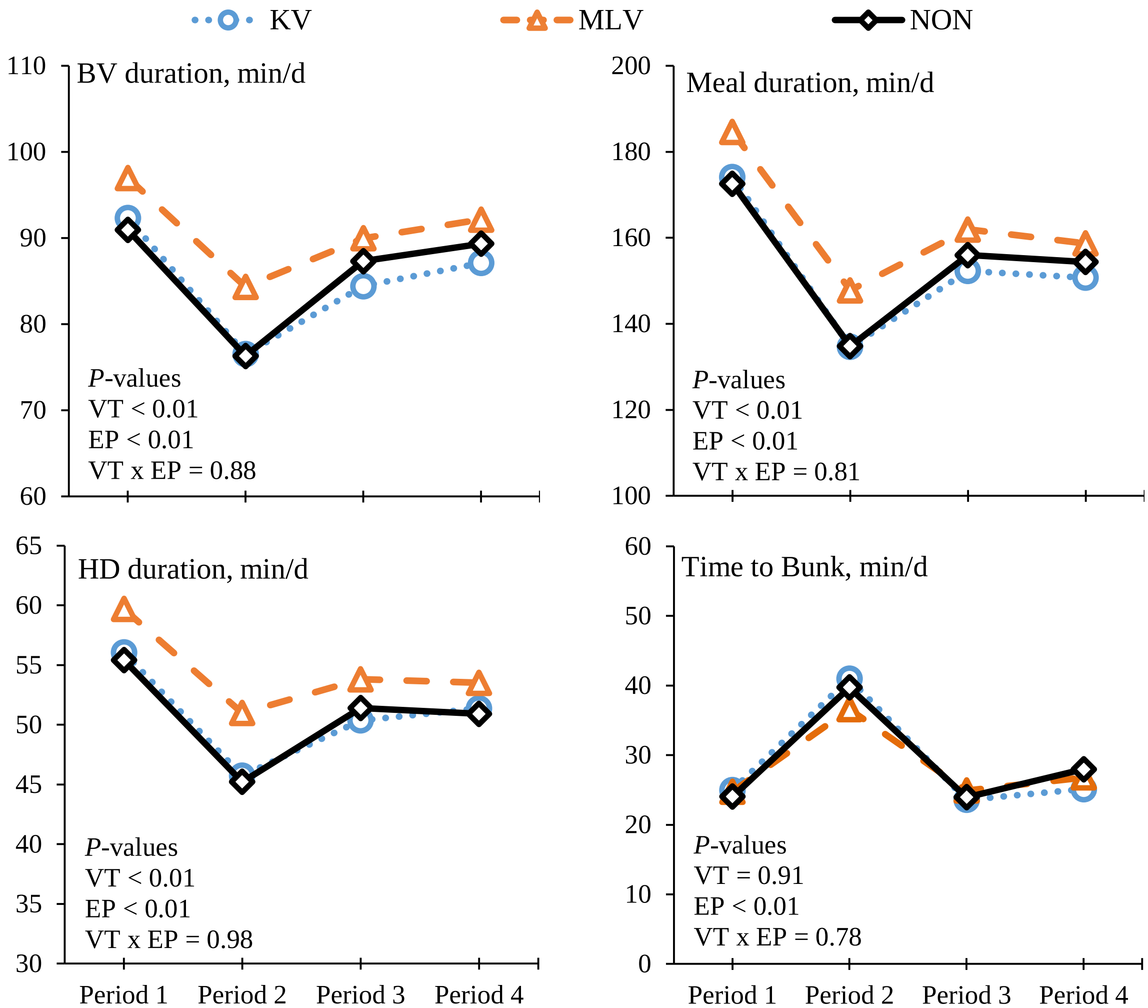

Figure 2. Effects of vaccine treatment and experimental period on BV, meal, and HD duration, and time to bunk.

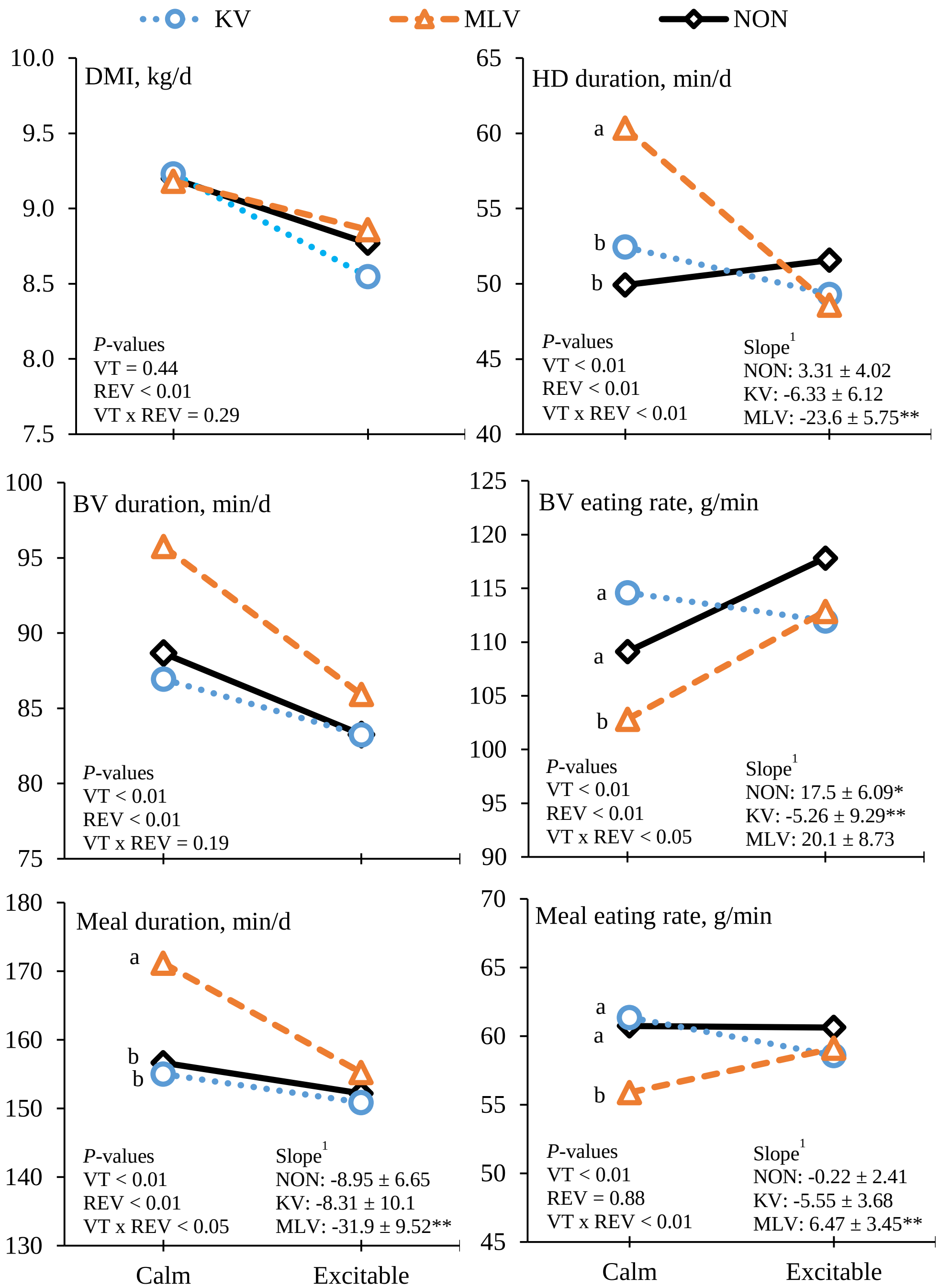

Figure 3. Effects of vaccine treatment and temperament on DMI and feeding behavior traits. [1]Slope = initial REV covariate ± SE for each vaccine treatment. *Slope of NON is significantly different than zero (*P* < 0.01). **Slope of KV or MLV is significantly different from slope of NON (*P* < 0.05). [a,b]Indicates difference (*P* < 0.05) within subclass means.

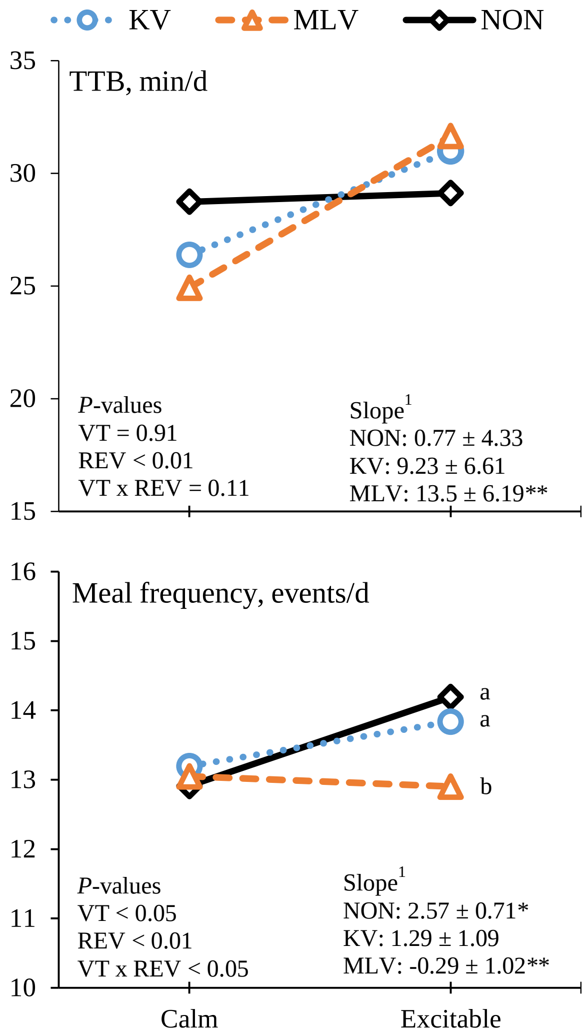

Figure 4. Effects of vaccine treatment and temperament on time to bunk (TTB) and meal frequency. [1]Slope = initial REV covariate ± SE for each vaccine treatment. *Slope of NON is significantly different than zero (P < 0.01). **Slope of KV or MLV is significantly different from slope of NON (P < 0.05). [a,b]Indicates difference (P < 0.05) within subclass means.

APPENDIX B

TABLES

Table 1. Definition of feeding behavior traits analyzed in this study.

Trait	Description
Bunk visit (BV) frequency, events/d	Number of BV events for each day
BV duration, min/d	Sum of the lengths of all BV events recorded each day
BV eating rate, g/min	Daily DMI divided by the daily BV duration
Head down duration (HD), min/d	Number of EID recordings each day multiplied by the read rate of the GrowSafe system
Meal frequency, events/d	Number of meal events for each day
Meal duration, min/d	Sum of the lengths of all meal events recorded each day
Meal eating rate, g/min	Daily DMI divided by the daily meal duration
BV/meal (BVM), events/meal	BV frequency divided by meal frequency
Time to bunk (TTB), min/d	Length of interval between feed delivery and the first BV event

Table 2. Frequency of temperament classification across vaccine treatments.

	Vaccine treatment (%)				
Temperament Classification[1]	NON	KV	MLV	χ^2	*P*-value
Calm	34.19	23.53	26.02		
Moderate	36.75	44.54	39.02	16.93	< 0.01
Excitable	29.06	31.93	34.96		

[1]Temperament classification was based on ± 0.5 SD from the mean initial REV of 0.00 ± 0.25.

Table 3. Effects of vaccine treatment and experimental period on DMI, performance, and feeding behavior traits to BVD viral challenge.

	Vaccine treatment (VT)				Experimental period (EP)					*P* values			
Trait	NON	KV	MLV	SE[1]	1	2	3	4	SE[1]	VT	EP	REV[2]	VT x REV
DMI, kg/d*	8.98	8.89	9.02	0.11	9.53[a]	8.01[c]	9.02[b]	9.31[a]	0.12	0.44	**< 0.01**	**< 0.01**	0.29
ADG, kg/d	1.11	1.08	1.15	0.04	0.94[c]	0.68[d]	1.58[a]	1.24[b]	0.05	0.25	**< 0.01**	0.08	0.29
G:F	0.122	0.121	0.129	0.005	0.100[c]	0.080[d]	0.178[a]	0.136[b]	0.005	0.20	**<0.01**	0.68	0.32
BV frequency, events/d[3]	69.6	69.0	70.1	1.2	84.4[a]	63.6[c]	67.9[b]	62.4[c]	1.4	0.62	**< 0.01**	0.36	0.08
BV duration, min/d	85.9[b]	85.1[b]	90.9[a]	1.7	93.4[a]	79.1[c]	87.2[b]	89.5[b]	1.9	**< 0.01**	**< 0.01**	**< 0.01**	0.19
BV eating rate, g/min	113.4[a]	113.3[a]	107.8[b]	2.2	111.0	109.7	113.2	112.2	2.6	**< 0.01**	0.55	**< 0.01**	**< 0.05**
HD duration, min/d[3]	50.7[b]	50.9[b]	54.5[a]	1.5	57.1[a]	47.3[c]	51.9[b]	51.9[b]	1.7	**< 0.01**	**< 0.01**	**< 0.01**	**< 0.01**
Meal frequency, events/d	13.5[a]	13.5[a]	12.9[b]	0.3	15.2[a]	12.9[b]	13.2[b]	12.0[c]	0.3	**< 0.05**	**< 0.01**	**< 0.01**	**< 0.05**
Meal duration, min/d	154.5[b]	152.9[b]	163.3[a]	2.3	177.2[a]	139.1[c]	156.7[b]	154.6[b]	2.6	**< 0.01**	**< 0.01**	**< 0.01**	**< 0.05**
Meal eating rate, g/min	60.7[a]	59.9[a]	57.5[b]	0.9	56.0[c]	59.8[b]	59.5[b]	62.1[a]	1.0	**< 0.01**	**< 0.01**	0.88	**< 0.01**
BVM, BV events/meal[3]	5.44[b]	5.28[b]	5.67[a]	0.12	5.89[a]	5.12[c]	5.41[b]	5.44[b]	0.13	**< 0.01**	**< 0.01**	**< 0.05**	0.97
TTB, min/d[3]	28.9	28.7	28.3	1.6	24.6[b]	39.1[a]	24.2[b]	26.6[b]	1.8	0.91	**< 0.01**	**< 0.01**	0.11

[a-d] Means within row with different superscripts differ ($P < 0.05$).

*Vaccine treatment x experimental period interaction was significant ($P < 0.05$).

[1]SE of the mean difference.

[2]initial REV = Average relative exit velocity (days 0 and 14) was utilized as a covariate.

[3]BV = Bunk visit, HD = Head down, BVM = Bunk visit per meal (BV frequency ÷ meal frequency), TTB = Time to bunk.

Table 4. Covariate regression slopes of initial REV for DMI, performance, and feeding behavior traits.

				Temperament[1]		*P*-value	
Trait[2]	Intercept	Slope	SE	Calm	Excitable	REV	VT x REV
DMI, kg/d	8.96	-0.94	0.19	9.19	8.73	**< 0.01**	0.29
ADG, kg/d	1.11	-0.11	0.08	1.14	1.08	0.08	0.29
G:F	0.124	-0.002	0.009	0.125	0.124	0.68	0.32
BV frequency, events/d[2]	69.5	1.97	2.22	69.0	69.9	0.36	0.08
BV duration, min/d	87.3	-12.7	2.81	90.5	84.1	**< 0.01**	0.19
BV eating rate, g/min	111.3	11.6	3.69	108.4	114.2	**< 0.01**	**< 0.05**
HD duration, min/d[2]	51.8	-8.38	2.44	53.9	49.7	**< 0.01**	**< 0.01**
Meal frequency, events/d	13.3	1.16	0.43	13.0	13.6	**< 0.01**	**< 0.05**
Meal duration, min/d	156.8	-16.2	4.04	160.9	152.8	**< 0.01**	**< 0.05**
Meal eating rate, g/min	59.4	0.24	1.46	59.3	59.5	0.88	**< 0.01**
BVM, BV events/meal[2]	5.47	-0.42	0.19	5.58	5.37	**< 0.05**	0.97
TTB, min/d[2]	28.8	7.45	2.61	26.9	30.7	**< 0.01**	0.11

[1]Temperament = mean initial REV ± 1 SD.

[2]BV = bunk visit, HD = head down, BVM = bunk visit per meal, TTB = time to bunk.