MANAGEMENT OF NEWLY RECEIVED FEEDLOT CATTLE AND THE EFFECTS OF BOVINE RESPIRATORY DISEASE ON FEEDLOT PERFORMANCE AND CARCASS ATTRIBUTES

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MANAGEMENT OF NEWLY RECEIVED

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ON FEEDLOT PERFORMANCE

AND CARCASS ATTRIBUTES

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NOMENCLATURE

α-GP	α-1-acid glycoprotein
ADG	average daily gain
APP	acute phase protein
BRD	bovine respiratory disease
BRSV	bovine respiratory synctial virus
BVDV	bovine viral diarrhea virus
BW	body weight
CRP	C-reactive protein
DM	dry matter
DMI	dry matter intake
FAPC	Robert M. Kerr Food and Agricultural Products Center
Fb	fibrinogen
FT	fat thickness
G:F	average daily gain:dry matter intake
HCW	hot carcass weight
Hp	haptoglobin
IBR	infectious bovine rhinotracheitis
IFN-γ	interferon gamma
IL-1	interleukin-1
IL-4	interleukin-4
IL-6	interleukin-6
IL-10	interleukin-10

IMF	intramuscular fat
IMPS	institutional meat purchasing specifications
KPH	estimated internal fat
LM	*longissimus* muscle
LKT	leukotoxin
LPS	lipopolysaccharide
ME	metabolizable energy
MH	*Mannheimia haemolytica*
NK	natural killer
OADDL	Oklahoma Animal Disease Diagnostic Laboratory
PDMI	dry matter intake as a percent of body weight
PI3	parainfluinza virus type 3
PI-BVDV	persistently infected with bovine viral diarrhea virus
SAA	serum amyloid-A
TNF-α	tumor necrosis factor-α
URT	upper respiratory tract
WBSF	Warner-Bratzler shear force
WSBRC	Willard Sparks Beef Research Center

CHAPTER I

INTRODUCTION

The bovine respiratory disease (**BRD**) complex continues to be an important and growing problem in the beef industry. From 1994 to 1999, when averaged over time, 12.6 animals died for every 1,000 that entered the feedlot (Loneragan et al., 2001). Of these deaths, 57.1% were attributed to BRD. The death rate from BRD rose significantly during the survey years, but deaths credited to other causes did not increase indicating that current management and treatment strategies have been unsuccessful in controlling BRD, despite improvements in available vaccines and available antibiotics (Babcock et al., 2006). In 1996, for every 1% increase in death loss, cattle feeders lost an estimated $5 to 10 per head marketed (Edwards, 1996). Economic losses related to death loss are not the only costs of BRD. Edwards (1996) also reported that around 70% of all disease in Midwestern feedlots was respiratory disease, and for every 10% morbidity rate, medicine costs alone would reach $2 per head marketed. Available data indicates that the diagnosis of BRD, which is done subjectively by visual observation (Galyean et al., 1999), is ineffective at identifying BRD cases. Supporting evidence has been developed by retrospectively correlating the presence of lesions on the lungs of feedlot cattle at slaughter. Cattle that were never treated for clinical signs of BRD have been reported

to have evidence of lung damage, and treated animals have been reported with no pulmonary lesions (Wittum et al., 1996; Gardner et al., 1999; Thompson et al., 2006; Schneider et al., 2009). When defining BRD incidence based on treatment records, pulmonary lesions, or a combination of the two, BRD resulted in lower average daily gain (**ADG**), lighter hot carcass weight (**HCW**), less estimated internal fat (**KPH**), and lower marbling scores than steers that remained healthy throughout the feeding period. Gardner et al. (1999) reported that decreased performance had a stronger correlation with lung lesions than treatment records. Steers with lung lesions and active bronchial lymph nodes at slaughter returned a net $73.78 less – 21% of this loss was attributed to cost of treatment, and 79% was due to lower hot carcass weight (8.4% less) and poorer quality grade (24.7% more US Standard carcasses). These performance characteristics indicate that BRD may have much more serious economic repercussions than treatment costs and death loss alone. In fact, the combination of treatment, death loss, and decreased efficiency have been estimated to cost the $800-900 million annually (Chirase and Greene, 2001).

Bovine Respiratory Disease is a multifaceted problem associated with multiple viral and bacterial pathogens and numerous risk factors and outcome possibilities (Duff and Galyean, 2007). The objectives of the experiments presented herein were to: 1) Evaluate a serum biomarker (haptoglobin) as a predictor of subsequent BRD incidence and animal performance in newly received feedlot cattle; 2) Evaluate the effects of clinically identified BRD on subsequent animal performance during finishing, carcass attributes, and measures of meat quality; 3) Evaluate nutritional management, specifically adaptation of newly received calves to a high-concentrate diet, on BRD incidence and

subsequent feedlot performance; and 4) Expand the current knowledge regarding prevention, identification, treatment, and subsequent management of BRD, ultimately reducing the economic impact of this disease on the beef industry.

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CHAPTER II

REVIEW OF LITERATURE

BOVINE RESPIRATORY DISEASE

Pathogens and Stressors

The complex known as Bovine Respiratory Disease (**BRD**) is a multifaceted disease that involves both bacterial and viral pathogens and has a variety of risk factors. *Mannheimia* (formerly *Pasteurella*) *haemolytica* (**MH**), *Pasteurella multocida*, *Histophilus somni* (formerly *Haemophilus somnus*), *Mycoplasma bovis*, infectious bovine rhinotracheitis (**IBR**; caused by bovine herpesvirus type 1), bovine viral diarrhea virus (**BVDV**), parainfluenza virus type 3 (**PI3**), bovine respiratory synctial virus (**BRSV**), and bovine respiratory corona virus are common pathogens associated with BRD (Roth and Perino, 1998).

When combined with the stress of weaning and transportation, which has damaging effects on the immune system (Blecha et al., 1984), these pathogens can lead to a high incidence of BRD. The exposure often occurs during shipping and at auction barns where cattle are co-mingled (Duff and Galyean, 2007). The pathogens involved in the BRD complex work in a synergistic fashion with detrimental results in the host animal (Burciaga-Robles, 2009). The principal bacterial agent responsible for the clinical signs

and pulmonary pathology associated with BRD is *Mannheimia haemolytica* biotype A, serotype 1 (Whitley et al., 1992; Booker et al., 2008b). It is hypothesized that management and environmental stress factors and/or viral infection alter the upper respiratory tract (**URT**) epithelium allowing this serotype, not normally found in the URT of healthy cattle, to colonize. Additionally, *M. haemolytica* possesses several virulence factors including endotoxin (**LPS**) and leukotoxin (**LKT**) which enable it to adhere to and colonize respiratory mucosal surfaces, evade host defense mechanisms, and disrupt pulmonary structure and function thereby having detrimental effects on the animal (Lafleur et al., 2001; Jeyaseelan et al., 2002).

Recent research regarding viral pathogens of involving field cases of BRD has focused on BVDV (Loneragan et al., 2005; Elam, et al., 2008; Hessman, 2009). Of primary concern are calves persistently infected with BVDV (**PI-BVDV**) animals. When cows are exposed to BVDV during d 45 to 120 of pregnancy the calves incorporate the virus into body tissues and their immune systems do not recognize it as a pathogen. Calves that are PI-BVDV cannot be distinguished from calves not PI-BVDV by visual or clinical observation, and PI-BVDV calves shed the virus their entire lives. Healthy, non-exposed animals will develop signs of disease and build an immune response to the virus when exposed to PI-BVDV animals (Burciage-Robles, 2009). The prevalence of PI-BVDV cattle arriving in commercial feedlots has been reported at 0.3% (Loneragan et al., 2005). The prevelance of PI-BVDV animals is increased in those who became chronically ill (2.6%) or died (2.5%). The presence of a PI-BVDV animal in a pen resulted in 43% greater risk of initial treatment for BRD, and 15.9% of initial respiratory disease cases were attributed to BRD. However, the effect of BVDV on ultimate health

and performance of groups of feedlot cattle is conflicting. Hessman et al. (2009) reported losses of $5.26 due to fatalities and $88.26 due to lost performance in pens of cattle that had direct exposure to PI-BVDV animals compared to unexposed pens. In other studies PI-BVDV exposure did not increase morbidity or decrease feedlot performance (O'Connor, et al., 2005; Elam et al., 2008). It is important to note, the calves in the controlled study of Elam et al. (2008) had previously been vaccinated at least once for BVDV prior to feedlot entry. Single and multiple vaccination against BVDV prior to PI introduction has been shown effective in preventing disease incidence (Step et al., 2009). The contrasting results in the literature may be because of the type of virus present in the PI-BVDV animals. In an evaluation of the effect of PI-BVDV exposure to non-exposed cattle, Booker et al. (2008a) concluded that pens containing animals PI-BVDV with BVDV type 1 had more BRD treatments and mortalities, but calves PI-BVDV with BVDV type 2 had no effect on the health of non-exposed calves.

Management Practices for Newly Received Calves with High Risk of BRD

Upon arrival at a feedlot, cattle can be placed in one of two categories: 1) high-risk and 2) low-risk (Edwards, 1996). High-risk cattle include freshly weaned calves, cattle that have been hauled long distances, cattle that have been assembled at auction markets, and cattle that appear to be highly stressed when they arrive at the feedlot. Low-risk cattle include yearling cattle that came from one source, cattle that arrive from preconditioning operations, and low-stressed calves that have been pre-weaned. When quantified, mixed gender groups, cattle from multiple sources, and increased transport distance were associated with increased risk for initial respiratory disease, while heavier

entry weights were primarily associated with decreased risk (Sanderson et al., 2008). In a review of preconditioning studies, Cole (1985) observed that preconditioning decreased feedlot morbidity 6% and mortality 0.7%. More recently Roeber et al. (2001) reported that calves of auction market origin had nearly double the BRD morbidity rates than calves weaned and vaccinated prior to feedlot entry. Similarly, Step et al. (2008) reported that calves weaned 45 d prior to shipment had lower BRD rates, regardless of vaccination status at weaning, than calves transported from the same ranch immediately at weaning or calves assembled at auction markets. Nutrition, including deficiencies caused by prior management and low intake by stressed calves upon arrival, can also impact the susceptibility of cattle to BRD (Galyean et al., 1999; Duff and Galyean, 2007). Upon arrival at a feedlot, cattle are usually vaccinated against many, if not all, of the pathogens that can be part of the BRD complex (NAHMS, 2000). They can also be vaccinated against Clostridial pathogens, treated for internal and external parasites, castrated, and dehorned. Prophylactic antibiotics may also be administered at this time. For example, tilmicosin phosphate (Micotil) has been shown, when given at processing in receiving trials, to decrease ($P < 0.01$) treatment for BRD (12%) compared with controls (43.6%, Galyean et al., 1993). Similarly, multiple administrations of prophylactic drugs may decrease incidence of disease and mortality (Step et al., 2008). In a study beginning in 1989 at the U.S. Meat Animal Research Center (Clay Center, NE), calves that could be classified “low-risk” received vaccinations against bovine rhinotracheitis, bovine viral diarrhea, and *Pasteurella haemolytica* and were given prophylactic Micotil (Wittum et al., 1996a). However, after these steps were taken, 29% were treated for BRD and 72%

of all animals had lung lesions present at slaughter. Of those that had lung lesions, 70% had never been treated for BRD (Wittum et al., 1996a).

Currently in feedlots, pen riders look at cattle and pull those they believe to be sick based on subjective criteria (Galyean et al., 1999). Signs, such as lack of attention, rapid breathing, reluctance to move or altered gait, and loss of all nasal discharge can be early indicators of BRD (Deyhle, 1996). The next stages of respiratory illness can result in loss of "fill," lowered ears, and low head carriage with nasal discharge. Cattle, which had previously recovered from BRD, exhibited symptoms much more quickly, because of possible prior lung damage, and must be pulled earlier than cattle that had never been sick before. All these symptoms are very subtle and require skilled personnel to decide which cattle should be treated. These personnel are difficult to find and train. The results of trials in which treatment records were kept and compared to lung lesions at slaughter indicate that the way feedlots diagnose and treat sick cattle are inadequate (Wittum et al., 1996a; Bryant et al., 1999; Gardner et al., 1999; Buhman et al., 2001; Thompson et al., 2006). In multiple studies more animals had lung lesions at slaughter than the number that were treated, and there were individuals who had never been treated but had lung lesions present at slaughter (Table 2.1). Therefore, it has been suggested that evidence of pulmonary lesions at slaughter should be combined with health records in order to measure the true incidence of respiratory disease (Bryant et al., 1999).

EFFECTS OF BRD ON FEEDLOT PERFORMANCE

The effects of BRD on performance of feedlot cattle has been investigated by several groups, both regarding the time when the disease process is occurring and the

effects of disease on subsequent performance and carcass characteristics. Feed intake by lightweight stressed calves averages only 1.5% of body weight (**BW**) during the first 2 weeks after arrival (Hutcheson and Cole, 1986; Galyean and Hubbert, 1995). In a summary of 18 experiments involving transit-stressed calves, only 83.4% of morbid calves and 94.6% of healthy calves had consumed any feed by d 7 (Hutcheson and Cole, 1986). In addition, measured dry matter intake (**DMI**) of morbid calves was 58, 68, and 88% of healthy calves across d 1 to 7, 1 to 14, and d 1 to 56, respectively.

Using a radiofrequency monitoring system, Sowell et al. (1999) recorded the frequency and timing of visits made to the feed bunk by newly received calves during receiving and growing periods. In one experiment, 94% of calves identified as healthy and 87% of morbid calves visited the feedbunk on the day of arrival, but 100% of healthy calves and only 91% of morbid calves had visited the bunk by day 3 (Trial 1). However, in another trial, only 13 and 10% of healthy and morbid calves, respectively, visited the feedbunk on d 1 (Trial 2). Again, all healthy calves had visited the bunk by d 4, but only 76 of morbid calves were observed at the feedbunk. In both trials, healthy calves had more overall feeding bouts per day and spent more time at the bunk daily than morbid animals, both over the first 4 d and throughout the 32-d trial. In Trial 1, 52% of calves were identified as morbid, and 82% were classified as morbid in Trial 2. In both trials, a similar 80% of morbid calves were identified within 10 days of arrival.

Using similar technology, Buhman et al. (2000) noted no difference in the frequency or duration of visits to the feed bunk between healthy and morbid calves for days 1 to 3, 4 to 5, or 6 to 10 after arrival. From day 11 to 27, sick animals had approximately 3 fewer visits and spent nearly 20 fewer minutes at the bunk daily than healthy animals.

However, from d 28 to 57 of the growing period, animals that had been identified as morbid visited the bunk nearly one additional time daily than did healthy animals. Notable are the days on feed when BRD was identified. Of the 170 calves enrolled in two studies, 43 were treated. Twenty-seven BRD treatments occurred by d 11, 12 between d 11 and 27, and 4 between d 28 and 56. The decrease in number of feedbunk visits and time spent at the bunk occurred at the time when BRD cases were prevalent.

Longer-term studies examining the effect that BRD has on feed intake after recovery are limited. Jim et al. (1993) sorted calves by elevated rectal temperature, classifying them as sick or healthy. Sick calves were required to have an elevated rectal temperature ($\geq$ 40.5°C) both 48 and 72 h after processing. Dry matter intake could not be measured during the first 48 h after processing because all animals were commingled from processing on d -3 to d 0, when sick animals were determined and pens were allocated. During that time sick animals lost 0.5 kg/d, while healthy calves gained 1.53 kg/d. However, during the next 27 d, sick animals gained 11% more than healthy animals while eating 0.3 kg/d less dry matter. Overall, d 0 to slaughter, average daily gain (**ADG**) and DMI was not different between sick and healthy calves, but the ratio of DMI:ADG (**F:G**) was 3.15% lower for animals identified as sick upon arrival. However, when DMI, and F:G were extrapolated from processing to d 0, no differences were observed. The improvement in efficiency likely resulted from shrink occurring in the sick animals between processing and allocation when they were likely not consuming feed. The subsequent compensatory response in early gain and efficiency was due to regaining lost gut fill. In their experiment an additional 6.6 and 4.7% morbidity was observed in sick

and healthy calves after allocation. Therefore, the differences in finishing DMI and efficiency could be biased by the timing of subsequent morbidity.

McBeth et al. (2001) segregated heifers by the number of BRD treatments (0 or 1) administered during a 42-d preconditioning period, observing subsequent finishing performance. At the beginning of the finishing phase, no difference in BW between healthy and morbid steers existed. However, ADG was increased 14.4 and 5.8% for treated heifers during d 0 to 28 and d 0 to 112, respectively. While DMI was not different at any time during the 140-d finishing period, the increase in ADG made treated heifers more efficient during the first 28 days on feed. In a combined viral and bacterial challenge experiment, Burciaga-Robles (2009) observed the largest decreases in DMI during, and immediately, after the challenge. Nevertheless, DMI continued to be slightly decreased in challenged steers compared with controls throughout the finishing period (112 d). In another study (Burciaga-Robles, 2009), fasting combined with MH challenge, resulted in greater serum concentrations of the acute phase protein haptoglobin (**Hp**) than fasting or challenge alone, indicating that fasted animals may have more severe disease than fed animals. It is apparent that newly received, highly stressed calves consume less feed than do more healthy calves exposed to fewer stress factors. In fact, current recommendations are that nutritionists increase the density of nutrients in diets of stressed calves so that animal requirements for nutrients are met even when intake is low (NRC, 2000). It is unclear, in commercial settings, whether disease causes decreased intake, or decreased intake is responsible for disease incidence. After recovery, DMI may remain low or be similar compared to non-treated animals.

The majority of the published reports regarding BRD and animal performance were conducted by retrospectively correlating treatment records with BW and ADG. In general, incidence of BRD during finishing results in decreased ADG and final BW (Gardner et al., 1999; Thompson et al., 2006; Schneider et al., 2009). Generally, within studies, initial BW was not correlated with subsequent BRD incidence (Gardner et al., 1999; Waggoner et al., 2007) or the success of antimicrobial treatment (relapse rate; Bateman et al., 1990). However, Montgomery et al. (2009) reported a linear decrease in arrival BW for heifers treated 0 to 3 times. A portion of the lost ADG observed in trials surveying cattle in commercial feedlots may be due to management of the morbid animals. Gardner et al. (1999) noted that the sick animals in their experiment were removed to hospital pens during treatment where they were fed diets that contained more roughage, and were, therefore, less energy dense. Decreased performance by calves moved to hospital pens may be due to decreased energy intake while in hospital pens and the necessity to re-adapt to high-energy diets and competition within home pens for bunk space.

There is evidence that, upon recovery, morbid animals experience compensatory gain compared to non-treated animals. This compensation may be due to recovering gastrointestinal fill or reduced competition for nutrients when cattle are moved from preconditioning pens to pasture (Montgomery et al., 2009). Thompson et al. (2006) reported decreased ADG by morbid cattle from d 0 to 35 in South African feedlots. However, no difference in ADG was seen throughout the remainder of the feeding period. The first 35 days on feed was also the period in which 87% of all BRD treatments occurred. In a large survey conducted in a commercial feedlot over multiple

classes of cattle, lighter cattle generally had higher overall incidence of BRD, and tended to be treated more times in the feedlot (Babcock et al., 2009). The reason for this could be related to the longer feeding period, and, thus, because lighter cattle have more time to be treated, they will be treated more. However, lighter cattle with arrival weights between 227 and 272 kg had fewer effects from BRD during subsequent finishing on performance and carcass merit than heavier animals (Babcock et al., 2009). This was likely because more days on feed between treatment and slaughter allowed calves with lighter initial BW more time to recover and compensate for lost gain that occurred during morbid episodes. Performance and carcass merit of cattle with heavier arrival BW were also affected more by treatment when that treatment occurred closer to slaughter. Treated cattle also tended to have fewer days on feed, decreased HCW, but increases in ADG (Babcock et al., 2009). The steers in the study of Gardner et al. (1999) and Montgomery et al. (2009) were slaughtered after constant days on feed, whereas those reported by Babcock et al. (2009) were slaughtered according to endpoint. Similarly, Waggoner et al. (2007) reported on steers slaughtered according to optimum marketing date, and observed decreased ADG, but similar HCW across cattle never treated vs. animals treated for BRD. However, cattle never treated were fed for an average of 7 days less than those treated 1 time and 19 days less than those that required 2 or more treatments. Average daily gain up to time of re-implant was similar between calves never treated and those that received one treatment and less for those that received three treatments (Roeber et al., 2001). However, ADG of cattle treated one time exceeded that of cattle never treated and cattle treated more than one time from reimplant to slaughter. It is important to note that the days on feed at the time of antimicrobial treatments were not reported, and cattle

in that study were harvested on a market-ready basis in three groups, approximately 30 d apart. While mean days on feed for each BRD treatment outcome group was not reported, it is likely that animals that had experienced morbidity were fed longer than those never treated. This is evidenced by the similar final BW observed between all three groups (Roeber et al., 2001).

Parallel to the observed differences in feedlot production characteristics, such as decreased intake and growth, BRD in cattle seems to be related to lighter and leaner carcasses (Larson, 2005). When morbidity was defined by the presence of lung lesions at slaughter, Gardner et al. (1999) observed morbid steers had HCW that were 94% of steers with no evidence of prior disease. In addition, when active bronchial lymph nodes were present, indicating an ongoing disease process, HCW were less than animals with no lesions. In general, evidence of prior morbidity was associated with decreased dressing percentage, internal fat, external fat, smaller *longissimus* muscle (**LM**) areas, and lower marbling scores. Similar results were noticed when carcass characteristics were examined based on BRD treatment records. Cattle that received more than one treatment for BRD had an additional 5% decrease in HCW compared to those that were treated only one time. Similarly, Roeber et al. (2001) reported a 3% decline in HCW in steers treated more than one time for BRD compared to those treated one time. However, in their report, no differences in HCW were observed between cattle never treated and those treated one time, and no differences in HCW across number of BRD treatments were reported by Waggoner et al. (2007). Although fewer differences in carcass weights and no differences in LM area were reported by Roeber et al. (2001), measures of carcass fatness were affected by BRD incidence. While internal fat was not different among

treatment groups, fat thickness, calculated yield grade, and marbling score were all greatest for cattle never treated, intermediate for those treated once, and lowest after multiple treatments. As a result of differences in marbling, the distribution of USDA quality grades has been shown to be affected by respiratory disease. Gardner et al. (1999) observed that treated steers, or steers with lung lesions, had a higher percent USDA Standard carcasses at the expense of Choice and Select, compared to healthy animals. Similarly, McNeill et al. (1996), in an evaluation of over 7,000 cattle, reported 39% of cattle never treated for respiratory disease graded USDA Choice or better, but only 27% that were treated were able to grade USDA Choice or better.

Differences observed in marbling scores and quality grades have generally not translated into differences in meat tenderness or palatability when measured. Gardner et al. (1999) measured lower Warner-Bratzler shear force (**WBSF**) of LM from steers with lung lesions present compared to those with healthy lungs after aging 7 d. However, when steaks were aged 14 or 21 d, no differences in WBSF were observed. Clinical treatment records were not associated with any differences in WBSF and no differences in the distribution of tender or tough steaks were observed based on treatment records or lung lesions. Roeber et al. (2001) also saw no difference related to treatment records in WBSF, tenderness, or juiciness when steaks were cooked to two different degrees of doneness. Warner-Bratzler shear force and palatability measurements were conduced only after 14-d aging. Similarly, Snowder et al. (2007) did not observe a significant correlation between respiratory disease and WBSF, or tenderness, juiciness, and flavor scores. However, no differences in marbling were observed in those cattle. They

suggested that, based on a moderate genetic correlation between BRD and WBSF, selection for resistance to BRD might have an undesirable effect on WBSF.

THE ACUTE PHASE IMMUNE RESPONSE

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). For many years it has been known that the sedimentation rate in stabilized blood from ill patients increases compared to healthy individuals. This is caused by several plasma proteins, called acute phase proteins (**APP**). Acute phase proteins are produced in the liver as part of an early defense mechanism in response to cellular injury (Eckersall and Conner, 1988). This injury can be a result of infection, inflammation, and advanced malignancies (Saini et al., 1998). Acute phase protein production is initiated by cytokines such as interleukin 1 (**IL-**1), interleukin-6 (**IL-6**), and tumor necrosis factor-α (**TNF-α**; Baumann and Gauldie, 1994; Table 2.2). As monocytes, macrophages, and neutrophils initially react to pathogens, these cytokines are produced, signaling multiple changes. Interleukin-1, IL-6, and TNF-α signal local production of low molecular weight mediators, such as prostaglandins, which induce dilation of local vasculature and blood leaking causing the redness and edema associated with infection. Systemically, they can induce the production of prostaglandin E_2, which acts on the adrenal pituitary to induce and regulate the febrile response. As a component of the acute phase response, the liver alters metabolism to increase or decrease the production of APP. Among the proteins whose production is increased are α-1-acid glycoprotein (**α-GP**), C-reactive protein (**CRP**), fibrinogen (**Fb**), Hp, and serum amyloid-

A (**SAA**), while albumin and transferrin are decreased. Table 2.3 lists the function of selected APP.

Multiple APP have been measured in cattle with the intended application of providing an alternative method for monitoring animal health, including respiratory disease (Peterson, 2004). Horadagoda et al. (1999) measured α-GP, Hp, and SAA from 81 cattle that had been diagnosed with acute or chronic inflammation, each from a number of different causes, and concluded that SAA and HP would be the most valuable for discrimination between acute and chronic inflammation. Research in this area, relative to feedlot cattle, has focused on serum Hp and SAA concentrations (Wittum et al., 1996b; Young et al., 1996; Carter et al., 2002; Berry et al., 2004b; Burciaga-Robles, 2009). Serum Hp has been shown to increase in response to experimental infection with MH (Conner et al., 1989) or BVDV (Ganheim et al. (2003). However, Burciaga-Robles (2009) reported that exposing naïve calves to PI-BVDV calves alone did not cause an increase in serum Hp concentration. In that study, intratracheal challenge with MH resulted in elevated serum Hp concentration, peaking 18 h after challenge and remaining greater than control animals for 96 h. Animals challenged with both pathogens had increased concentrations of pro-inflammatory cytokines, especially IL-1 and TNF-α, compared to non-challenged controls and both BVDV and MH challenge alone. These results indicate that serum Hp concentration might be a valuable biomarker for detecting and monitoring disease caused by common BRD pathogens.

The duration of an acute phase response is relatively short lived (Peterson, 2004). The increase of up-regulated APP can happen as early as 4 h or as late as 18 h after challenge. Acute phase proteins have been classified into two groups (Type I and Type

II) based on the cytokines that induce production and length of increased circulation (Peterson, 2004) Type I APP are primarily induced by IL-1 and TNF-α and typically have a more rapid elevation and normalization in concentration than Type II APP. Type II APP are induced by IL-6 – for some APP, IL-6 is inhibitory – and tend to peak later, but remain elevated in serum concentration for up to 2 weeks. Proinflammatory cytokines have a short half-life, and, thus, one might not expect inhibitory compounds to be necessary (Baumann and Gauldie, 1994). However, interleukin-4 (**IL-4**) and interleukin-10 (**IL-10**), produced by TH2 lymphocytes, monocytes, macrophages, and B-cells, inhibit the production of the proinflammatory cytokines. Wittum et al. (1996b) measured increased serum Hp in calves showing clinical signs of BRD. In that study morbid calves were either administered antimicrobial therapy or not administered antimicrobial therapy. Recovery was monitored in both groups, and a sample for serum Hp measurement was collected 10 d after initial diagnosis, at which time calves in both groups showed no clinical signs of disease. The decrease in serum Hp compared to the initial sample was greater for animals that received treatment than untreated animals. Carter et al. (2002) observed that serum Hp concentrations in morbid cattle were decreased after disease resolution. Burciaga-Robles (2009) observed elevated Hp, though decreasing from peak concentration, in challenged animals through 96 h after bacterial challenge. Haptoglobin concentration, measured in response to shipping stress, remained elevated compared to pre-shipping values for 17 or 7 d (Exp. 1 and 2, respectively; Arthington et al., 2003). Similarly, after an 1,800 km transport, Qiu et al. (2007) measured peak Hp (three fold increase compared to pre-shipment concentration) 24 h

after arrival, and concentration remained elevated through the last measurement 72 h after arrival.

Young et al. (1996) reported associations between serum Hp levels and respiratory disease but showed that Hp alone could not predict clinical disease. However, Carter et al. (2002) and Berry et al. (2004b) reported that Hp alone could be used as a diagnostic tool to make management decisions regarding BRD. In the study of Carter et al. (2002), α-GP, Fb, Hp, and SAA were measured in newly received calves upon arrival in the feedlot. No differences were detected in α-GP or SAA regardless of the subsequent BRD incidence, and the Fb response was inconsistent, being greatest for steers that were never treated, least for steers treated one time, and intermediate for those treated 2 or more times for BRD. However, serum Hp increased as the number of subsequent treatments for BRD increased. Contrary to Alsemgeest et al. (1994) the ratio of Hp:SAA was not as successful in predicting BRD incidence as Hp alone. The APP, α-GP, Fb, Hp, and SAA might be appropriate for monitoring response to treatment, as all generally decreased between the time an animal was initially treated and recovered (14 d later). Berry et al. (2004b) showed positive correlations between Hp concentrations sampled at processing and the number of subsequent treatments for signs of BRD. The same report, though, did not find differences in SAA concentrations among steers treated different numbers of times for BRD, and Fb was only increased in steers treated 2 or more times. Step et al. (2008) measured increased serum Hp concentration as the number of antimicrobial treatments increased from 0 to >1. However, regression analysis showed only a poor correlation between arrival Hp concentration and the number of eventual antimicrobial

treatments, and Holland (2006) observed no statistical difference in the arrival serum Hp concentration for cattle that remained healthy vs. those that were treated for BRD.

The concentration of Hp in serum of healthy cattle has been reported as undetectable (Eckersall and Conner, 1988). However, more recent literature has measured increased Hp in response to transportation (Arthington et al., 2003; Arthington et al., 2005; Qie et al., 2007; Arthington et al., 2008), injury prior to slaughter (Saini et al., 1998) or increasing dietary concentrate level (Ametaj et al., 2009). However, the stress of regrouping and relocation was insufficient to cause increases in Hp in another study (Gupta et al., 2005), and dietary energy and starch level did not affect Hp concentration of newly received calves (Berry et al., 2004b). In calves with few BRD risk factors (adequate health and nutrition management; 28-d weaning period prior to shipment; not commingled), Hp was increased from pre-shipment levels after an 1,800 km transport, peaked near 3 times pre-shipment values 24 h after arrival, and remained high through 72 h after arrival (Qiu et al., 2007). Transportation, but not commingling was shown to increase serum Hp in one study (Arthington et al., 2003). In calves with similar pre-weaning management, Arthington et al. (2005) and Arthington et al. (2008) reported calves weaned prior to shipment (84 days of age) had lower Hp after arrival at the feedlot than those weaned at shipment (300 days of age). Serum Hp concentration measured upon arrival was similar for commingled calves sourced at an auction with unknown prior management and calves sourced from one ranch and weaned the day of shipment to the feedlot (Step et al., 2008). However, steers from the same ranch of origin that had been weaned 45 d prior to shipment or weaned and vaccinated 45 d prior to shipment had approximately 33% the concentration of Hp upon arrival. In the Florida studies no

incidence of BRD morbidity was observed (Arthington et al., 2003; Arthington et al., 2005; Arthington et al., 2008) or reported (Qiu et al., 2007), while the experiment reported by Step et al. (2008) observed a four fold increase in total morbidity rate in market origin or newly weaned steers compared to pre-weaned calves. Based on these data, the confluence of risk factors (transportation, stress, auction market origin, and recent weaning) and serum Hp concentration could indicate that Hp concentration, as a gauge of the risk for developing BRD, may be related more to stress than pathogen challenge. Correlations between measures of pathogen exposure, such as antibody titers, virus shedding, or bacterial cultures, were not reported in these studies. Some management practices on the ranch of origin that reduce the risk of BRD after arrival work by increasing the animal's resistance to challenge pathogens (Kirkpatrick et al., 2008).

Serum Hp concentration in the feedlot has also been negatively correlated with ADG in calves that were weaned at shipment but not in those that were pre-weaned (Arthington et al., 2005). As previously mentioned, no BRD morbidity was observed, indicating that these animals were suffering from a sub-acute infection, and a related acute phase response, or the acute phase response induced by stress of normal management in healthy calves had sufficient effects on nutrient metabolism and animal growth to be similar to the response associated with clinical disease (Le Floc'h et al., 2004; Burciaga-Robles et al., 2009).

CATTLE ADAPTATION TO HIGH-CONCENTRATE DIETS

Ruminal Acidosis

Digestive disturbances are the second leading cause of morbidity and mortality in feedlot cattle, and ruminal acidosis is one of the most common and well known of these disorders (Owens et al., 1998; Nagaraja and Lechtenberg, 2007). Acidosis is defined as a decrease in the alkali in body fluids relative to the acid content. However, in ruminants the term is used to describe acidodic conditions in the rumen. Ruminal acidosis is characterized by excessive consumption of readily fermentable carbohydrates, the presence of free glucose, the proliferation of amylolytic and glucolytic bacteria, and the subsequent accumulation of organic acids. The levels of these acids can exceed the capacity for absorption across the ruminal epithelium and metabolism within the rumen by microorganisms. According to ruminal pH, acidosis is classified as acute (pH < 5.2) or subacute (pH < 5.6). In cases of acute ruminal acidosis, organic acids can spill into blood, thereby decreasing blood pH. Metabolic acidosis, combined with an increase in endotoxins, can cause an increase in inflammatory mediators, and clinical rumenitis, laminitis, polioencephalomalacia, and liver abscesses. The primary etiologic agents include *Selenomonas ruminantium, Streptococcus bovis,* and *Lactobacilli* species, although the majority of ruminal bacteria can utilize starch as a substrate. *S. bovis* is a facultative anaerobe that replicates very rapidly when starch is abundantly present producing lactic acid. *Lactobacilli* species are more tolerant to the resulting lower pH and produce lactic acid. Lactic acid is typically an intermediate in ruminal fermentation and is metabolized to volatile fatty acids by *Magasphaera elsdenii* and other species. Ultimately, as pH decreases these lactate utilizers cannot survive. Therefore, lactate can

build up, increasing the damage and further lowering ruminal pH. Owens et al. (1998) extensively reviewed ruminal acidosis and common products available to buffer ruminal pH, decrease acid produced, and lower the incidence of acidosis.

Adaptation Programs

When cattle are received into feedlots they have likely been freshly weaned prior to shipment, withheld from or had erratic access to feed and water while in marketing channels, or grown on harvested or standing forage (Loerch and Fluharty, 1999). In each case, the ruminal environment in these animals is unprepared to safely handle readily available carbohydrates (Brown et al., 2006). When expressing ingredient costs on a dollar per unit of energy basis, cereal grains have a higher value than roughages (Eng, 1995). In addition, because of increased cost of handling roughages, which are less dense, and milling difficulties associated with roughages, feedlot operators desire to feed higher concentrate rations. Traditionally, cattle feeders have started cattle on a diet that contains a lower percent concentrate, and gradually replaced forage with grain over a period of days until the forage:concentrate ratio of the final finishing diets is reached (Brown et al., 2006; Krehbiel et al., 2008). Typcially, a series of transition or "step-up" diets with each subsequent diet having a lower roughage amount is used. A period of 21 to 28 d and 3 to 6 transition diets are common (Krehbiel et al., 2006). Vasconcelos and Galyean (2007) surveyed feedlot consulting nutritionists. Of the 29 who replied, 22 used multiple step-up diets or multiple step-up diets and other methods. The number of transition diets used ranged from 2 to 5, with 2 being the mode, and each diet was fed on average 7.2 d (range = 4.0 to 11.0 d). The typical concentration of roughage in finishing

diets was 4.5 to 13.5% of DM (mode = 9.0%), and of those who responded, most nutritionists started cattle on diets containing 39.9% roughage, with a range of 27.5 to 46.0%.

While understanding of the etiology of acidosis is extensive (Owens et al., 1998), appropriate amounts and number of concentrate increases to maximize overall feed intake and cattle performance is less clear (Brown et al., 2006). Strong correlations exist between DMI and ADG, saleable weight, and net return of feedlot cattle (Krehbiel et al., 2006). Therefore, an appropriate adaptation program that encourages long-term high feed intake is desired. Brown et al. (2006) reviewed the literature and concluded that in the majority of studies, initial diets generally contained 55 to 70% concentrate, and when ad libitum consumption was allowed, 14 d was the minimum necessary time for adaptation to a high-(92 to 95%)-concentrate diet. They noted that due to the small (both cattle numbers and number of cattle in pens) nature of these studies effect of diet adaptation on metabolic disturbances, such as bloat or sudden death, could not be inferred. Pritchard and Bruns (2003) recommended bunk management strategies to decrease the day-to-day variation in feed intake for pens of cattle and prevent dramatic decreases in feed intake, and, thus, improve cattle performance compared with ad libitum access to the diet. However, individual tolerance for carbohydrate varies greatly within cattle (Bevans et al., 2005), and there is evidence that an individual animal's daily intake within a pen likely has greater variation than that of the pen as a whole (Sowell et al., 1999; Buhman et al., 2001). Bevans et al. (2005) suggested that adaptation programs be tailored for the most susceptible (health impaired, poor performing, etc.) cattle within a pen.

Performance trials examining methods for adaptation of cattle to finishing diets have been reported. Published reports compare ad libitum use of step-up diets with either limiting maximum intake approaches (Xiong et al., 1991; Bartle and Preston, 1992) or restricted feeding of a 90 to 92.5% concentrate diet (Bierman and Pritchard, 1996; Weichenthal et al., 1999; Choat et al., 2002). Xiong et al. (1991) suggested that controlling peaks in DMI could be accomplished by using multiples of maintenance energy requirements to provide an upper limit of feed intake. Their goal was not to decrease or program intake, but rather establish a limited maximum intake where, by decreasing variation in daily feed intake, cattle could still consume, on average, equivalent or greater quantities of feed across a feeding period. They conducted an experiment in which intake was restricted to 2.3, 2.5, and 2.7 times maintenance during weeks 1 through 3 of adaptation, followed by 2.9 times maintenance through finish compared with normal ad libitum bunk management in a factorial arrangement with increasing roughage concentration (9 of 18% of dry matter; **DM**) and three densities of steam-flaked sorghum. They observed an interaction in which steers fed intake limited by multiples of maintenance gained more than steers fed ad libitum through 56 d on the 9% roughage treatments, but limited intake steers gained less than ad libitum steers when fed 18% roughage. Over the entire finishing phase, steers fed 18% roughage ad libitum gained more than those limited by maintenance, while no difference in ADG for 9% roughage diets was noticed due to feeding management. This discrepancy was driven by increased DMI for ad libitum steers consuming 18% roughage compared to limited steers, while ad libitum and limited steers had similar DMI of a 9% roughage diet. No difference in G:F was noted. In a similar experiment, Bartle and Preston (1992) restricted

intake of yearling steers based on multiples of maintenance using two programs (2.1, 2.3, 2.5, and 2.7 [2.7MM] or 2.3, 2.5, 2.7, 2.9 [2.9MM] times maintenance requirements during weeks 1, 2, 3, and 4, respectively) vs. ad libitum. Similar to Xiong et al. (1991), intake after adaptation until finish was limited according to the high multiple of maintenance amount for each treatment (2.7 or 2.9 times maintenance for 2.7MM and 2.9MM, respectively). In their experiment, DMI decreased 4.7 and 5.8% for 2.7MM and 2.9MM compared to ad libitum, respectively, during the adaptation period. The 2.7MM steers also had numerically increased ADG and a tendency for greater G:F. Over the entire experiment, 2.7MM tended to improve ADG 6% and G:F 4% compared with ad libitum steers while 2.9MM steers were intermediate. In both experiments, carcass characteristics were not affected by feeding management.

The other primary method that has received attention, compared to ad libitum feeding, is limit-feeding the high-concentrate diet beginning d 1 of the finishing period. Bierman and Pritchard (1996) and Weichenthal et al. (1999) observed a 6 to 10% decrease in overall DMI and a 7.8 to 13% improvement in G:F for yearling cattle started on a high-concentrate diet with a limited intake on d 1 compared with ad libitum step-up diets. Similarly, Choat et al. (2002) observed decreased DMI of yearling steers adapted using restricted feeding of the final diet, as well as 3.8% decreased ADG. This was due to a 27% decrease in ADG from d 0 to 28 despite a compensatory response in restricted steers from d 57 to 70. Combined with the lower DMI, efficiency was similar between treatments in that experiment. In Exp. 2 of the same report (Choat et al., 2001), steer calves had lower adaptation period and overall DMI and ADG when restricted intake of the final diet compared to an ad libitum adaptation program.

The management of cattle after the adaptation period does differ between these studies. In some experiments, cattle were managed according to their limited maximum (Xiong et al., 1991; Bartle and Preston, 1992) or prescribed intake (Bierman and Pritchard, 1996) protocols through finishing. However, cattle that were limit-fed the final diet were allowed ad libitum intake after ad libitum intake was achieved through slaughter in other experiments (Weichenthal et al., 1999; Choat et al., 2002). Yearling steers reached ad libitum intake within 3 weeks (Weichenthal et al., 1999) or 36 days (Exp. 1; Choat et al., 2002) with no reported interruptions in rate of DMI increase. However, the calves in Exp. 2 (Choat et al., 2002) showed more variation in the rate of DMI increase, including a plateau in intake during d 25 to 28, and equivalent DMI compared with traditionally adapted cattle was not reached until nearly day 50. Choat et al. (2002) concluded that the decreased performance by calves was due to a longer than desired restriction in energy intake.

In previous experiments, carcass characteristics were generally not different among adaptation treatments. Steers adapted to a high-concentrate diet using limited intake of the finishing diet had greater yield grades and 12th-rib fat thickness (Weichenthal et al., 1999), and tended to have increased marbling scores (Bierman and Pritchard, 1996) compared to those adapted with ad libitum feeding of step-up diets. Aside from HCW, which resulted from decreased ADG during Exp. 2 of Choat et al. (2002), no differences in carcass characteristics were observed.

A third approach which is gaining acceptance in feedlots, but has not received attention in the literature, is a two-ration adaptation method (Krehbiel et al., 2006). In this method, only 2 rations (starter and finisher) are used. The starter is fed initially, and

after approximately 3 to 5 days, a proportion of finisher is added. Similar to multiple step-up diets, in which concentrate:roughage ratios are increased gradually by switching between the diets, in a two-ration approach, concentrate:roughage ratios are increased gradually by changing the proportion of each diet fed daily. Feedlot operations can be more efficient because only two rations must be mixed and delivered, reducing milling requirements, and the number of partial truck loads that must be delivered each day. In addition, it is possible to decrease the magnitude of each energy increase as the adaptation program proceeds. In a step-up ration program, the difference in diet roughage concentration may be 10%. For a scenario where cattle are fed thrice daily, the percent concentrate in total feed delivered could go from 65% to 68.3%, to 71.6%, to 75% by replacing one feeding with the 75% concentrate ration each day for three days. Similarly by feeding starter and finishers in different feedings and at different proportions of the total feed call at each feeding, smaller increments can be easily produced and a smoother transition seems possible. Coordination of this approach requires more intensive management, and the risk of mistakes becomes greater. In addition, the assumption must be made that all cattle eat equal portions of each feeding daily. In their survey, Vasconcelos and Galyean (2007) reported that only 6 of 29 nutritionists used a 2-ration approach in client feedlots.

Dietary adaptation and respiratory disease

The rate of treatment of feedlot cattle for signs of BRD is greatest early in the feeding period (Babcock et al., 2009). However, data on the effect of dietary adaptation on BRD incidence is limited. Due to the low feed intake observed in stressed calves

(Hutchison and Cole, 1986), risk of acid accumulation would seem low, but because morbid calves may not be consuming feed at all, rapid movement to higher-energy diets might increase the risk of acidosis when morbid calves resume intake. Several studies conducted at New Mexico State University were reviewed by Rivera et al. (2005). In summary, decreasing roughage concentration in the diets of newly received, high-risk calves resulted in slightly higher BRD morbidity rates (1.35% by decreasing roughage 20%). However, improved ADG with higher energy diets overwhelmed the costs of morbidity, and net returns were greater with higher-energy diets. Diets in the 6 studies ranged from 100% grass hay to 25% roughage in a mixed ration. Therefore, results could be confounded by crude protein concentrations, and energy density cannot be separated from concentrate:roughage ratio. In an attempt to separate these effects, Berry et al., (2004a) fed diets with high (48% of ME) or low (38% of ME) starch at two energy densities (35 and 45% roughage). Performance and overall morbidity were not affected by energy concentration, but morbid calves consuming more energy had lower shedding of bacterial respiratory pathogens. In addition, lower starch tended to result in less morbidity. No affects of dietary energy or starch on APP production were observed (Berry et al., 2004b). Using a LPS challenge model, Reuter et al. (2008) observed an increased pro-inflammatory response from calves consuming a low-concentrate (30%) diet ad libitum, followed by a higher-concentrate (70%) diet at the same energy intake, with the least response from calves consuming 70% concentrate ad libitum. In addition, pre-challenge the cytokine IL-4, which regulates the proinflammatory response, was non-detectable in steers on the 30%-concentrate diet. Reuter et al. (2008) suggested that increased morbidity in calves fed higher-energy diets was due to less protection by the

innate immune system in those calves, and both lower energy and dietary ingredient roughage could enhance the inflammatory protection against disease. The possibility also exists that increased morbidity rates observed in calves started on higher concentrate diets are misdiagnosed due to inflammatory response initiated by diet. Leedle et al. (1995) monitored health of fistulated cows being adapted to a high-concentrate (90%) diet over 4 weeks. They observed increased rectal temperature of cows after adaptation to 90% concentrate as well as increased respiration rate. This was likely due to increased venous CO_2 as a result of increased fermentation. A decrease in blood pH was also observed. Adaptation to growing, and subsequent finishing diets was associated with an inflammatory and acute-phase response as well (Ametaj et al., 2009). A non-specific inflammatory response due to digestive upset associated with dietary adaptation may cause sickness behavior (Tizard, 2008) and pen riders may misdiagnose these animals as respiratory disease.

SUMMARY AND CONCLUSIONS FROM THE LITERATURE

Current literature regarding BRD indicate that this disease, through its complex and multi-faceted interaction of pathogens, stressors, risk factors, and outcomes remains an important and costly problem in beef cattle production. There is also evidence that, despite recent advances in the understanding of BRD and improvements in vaccines, antibiotimicrobials, and management practices, morbidity and mortality rates in commercial feedlots are increasing. While certain biomarkers, such as Hp, have been associated with BRD, when retrospectively looking at treatment records, controlled studies should be undertaken to evaluate their use as tools in classifying animals

according to risk of BRD. In addition, the effect of biomarker level on animal performance should be addressed. Published literature regarding the effect of BRD on animal growth and carcass merit has focused on correlating treatment records, lung lesions, or both with animal performance or was based on experimentally challenged animals. Knowledge is lacking on the effect of clinical BRD on subsequent feedlot performance (especially DMI and efficiency), carcass merit, and characteristics of meat product quality using animals with disease developed from natural challenge. Finally, nutrition has been linked with animal immunity and disease incidence, and programs used to adapt cattle to high-concentrate finishing diets have been shown to affect performance of feedlot cattle. However, the interaction between dietary adaptation and BRD morbidity rates in high risk calves, as well as feedlot performance of these animals, has not been explored. The experiments presented in this dissertation were designed to address specific questions and improve our understanding of these issues.

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Table 2.1. Observed frequency of pulmonary lesions at slaughter from selected publications[1].

	Total[2]		Healthy[2]		Treated[2]	
Publication	n	%	n	%	n	%
Bryant et al., 1999[3]						
MARC	439	42.0	366	42.3	73	40.0
Commercial	599	53.9				
Buhman et al., 2000[4]	170	75.9	108	83.3	60	88.3
Removed					38	97.4
Sick					22	72.7
Epperson et al., 2003	391	44.2				
Gardner et al., 1999[5]	204	33	102	29.0	102	37.0
Lymph				9.0		14.0
Reinhardt et al., 2009	20,965	3.4	17,366	2.9	3,599	5.7
1 treatment[6]					2,253	4.9
$\geq$ 2 treaments[6]					1,346	7.0
Schneider et al., 2008	1,665	61.9	1,529[7]	60.6	136[7]	74.0
Thompson et al., 2006	2,036	42.8	1,575	38.5	461	57.4
1 treatment[6]					380	55.4
$\geq$ 2 treaments[6]					81	66.7
Wittum et al., 1996a	469	72	306	68	163	78.0

[1]Not all publications contained the same information regarding treatment history. Additionally, different protocols were used to identify calves for BRD treatment, and different lung scoring procedures were used. Indicated here is the frequency of any evidence of lung damage.

[2]Total represents the total cattle whose lungs were evaluated during the experiment; Healthy are those that were never treated; and Treated received antimicrobial treatment for signs of BRD.

[3]Lungs examined from a population of cattle raised and fed at the US Meat Animal Research Center (MARC), Clay Center, NE and commercial calves fed in Nebraska and Kansas feedlots (Commercial).

[4]Removed includes calves removed from pens for signs of BRD and antimicrobial treatment, but not classified as 'sick' according to criteria (rectal temperature, ruminal fill, attitude, nasal or ocular discharge, lung auscultation score, pulse oximetry, white blood cell count, and haptoglobin concentration. Sick calves include those removed and treated for signs of BRD but also met minimum standards for the previously mentioned criteria.

[5]Lymph, percent of lungs containing lesions and also had active lymph nodes.

[6]1, $\geq$2: number of BRD treatments received.

[7]Calculated based on reported 8.17% rate of BRD in the overall study (n = 5,976). Lung lesion presence was only recorded from 1,665 animals.

Table 2.2 Functions of selected cytokines and acute phase proteins[1].

Protein	Functions
Cytokine	
Interleukin-1	induction of the hepatic acute phase response
Interleukin-4	inhibition of the acute phase response
Interleukin-6	induction of fever
Interleukin-10	inhibits monocyte/macrophage synthesis of IL-1, IL-6, and TNF-α
Tumor necrosis factor-α	induction of IL-1 production; activation of T-, B-, and NK cells; induction of IL-2 in T-cells
Acute Phase Protein	
Antichymotrypsin, antitrypsin, thio-statin, macro-globulin	antiproteases
C-reactive protein	complement activation and opsonization; modulation of monocytes and macrophages, including cytokine production; binding of chromatin; prevention of tissue migration of neutrophils
Fibrinogen	blood coagulation; scarring and long-term effects of inflammation in tissues
Haptoglobin	binding hemoglobin; bacteriostatic effect; stimulation of angiogenesis; role in lipid metabolism/development of fatty liver in cattle; immunomodulatory effect; inhibition of neutrophil respiratory burst activity
Serum amyloid A	transport cholesterol from dying cells to hepatocytes; inhibit fever; inhibit the oxidative burst of neutrophilic granulocytes; chemotaxic effect on monocytes, polymorphonuclear leucocytes and T cells; inhibit platelet activation

[1]Adapted from Peterson (2004) with information from Baumann and Gauldie (1994).

CHAPTER III

SORTING HEIFERS WITH HIGH RISK OF BOVINE RESPIRATORY DISEASE BASED ON ARRIVAL SERUM HAPTOGLOBIN CONCENTRATION

ABSTRACT: Two experiments were conducted to evaluate the effect of arrival serum haptoglobin (Hp) concentration on receiving growth performance and bovine respiratory disease (BRD) morbidity and mortality of newly received calves. In Exp. 1, 360 heifers (initial BW = 241 ± 16.6 kg) were shipped 957 km from a Kentucky order buyer facility to central Oklahoma, grouped by arrival serum Hp concentration, and randomly allotted into receiving pens within group. Groups were LOW (< 1.0 µg/mL; n = 3 pens); MED (1.0 to 3.0 µg/mL; n = 4 pens); and HIGH (> 3.0 µg/mL; n = 5 pens) serum Hp concentration. Animal performance and incidence of BRD morbidity and mortality were monitored during a 63-d study. Mean ± SEM arrival serum Hp concentrations were 0.60 ± 0.20 µg/mL for LOW; 1.90 ± 0.19 µg/mL for MED; and 7.80 ± 0.15 µg/mL for HIGH (linear, $P < 0.001$). Initial BW was greater for LOW and HIGH compared to MED (quadratic, $P < 0.001$), although by d 7, increased (quadratic, $P = 0.02$) ADG by LOW (0.58 kg/d) and MED (0.77 kg/d) compared to HIGH (0.17 kg/d) resulted in similar ($P \geq 0.25$) BW. Average daily gain tended ($P \leq 0.09$) to be linearly decreased as Hp concentration increased from d 8 to 14 and from d 1 to 63; no other differences ($P \geq 0.12$) in ADG or BW were noted throughout the experiment. Dry matter intake was linearly ($P \geq 0.12$) decreased with increasing Hp groups from d 1 to 21, and tended ($P = 0.06$) to be

decreased from d 1 to 63. Total BRD morbidity was linearly increased ($P = 0.05$) with increasing Hp concentration, and this was due to an increase ($P = 0.03$) in the number of heifers that required 3 antimicrobial treatments for BRD. At slaughter, no differences ($P \geq 0.11$) in carcass characteristics were observed among Hp groups. In Exp. 2, 345 (initial BW = 240 ± 22.8 kg) steer calves were shipped 107 km from Oklahoma National Stockyards (Oklahoma City, OK) to the research facility, grouped by arrival Hp concentration (ND, none detected or PRES, present) and allotted to receiving pens (n = 6 pens/group) where performance and BRD morbidity and mortality were monitored for 42 d. Arrival Hp concentration in PRES steers was 0.451 ± 0.057 µg/mL. Steers with measureable Hp on arrival weighed less ($P \leq 0.009$) throughout the study, gained less ($P = 0.04$) from d 1 to 7, and had lower ($P = 0.01$) DMI from d 1 to 42 than ND steers. Overall morbidity was not different between groups, but the odds ratio for requiring 3 treatments was 2.73 for PRES compared to ND ($P = 0.03$). Arrival serum Hp concentration did not affect overall growth performance, but may be a beneficial tool for making management decisions to reduce risk of BRD morbidity in high risk calves.

Key words: acute phase protein, bovine respiratory disease, calves, growth, haptoglobin

INTRODUCTION

Newly received feedlot cattle are submitted to multiple stressors and pathogens as they travel through marketing channels between the ranch of origin and the feedlot (Duff and Galyean, 2007). Associated with these stressors is incidence of Bovine Respiratory Disease (**BRD**), the most important and costly disease of feedlot cattle. A reported 75% of feedlot morbidity and 50% of mortality can be attributed to BRD (Smith, 1998), and recent surveys would indicate that despite improved vaccines and antimicrobial drugs, BRD mortality rates are increasing (Loneragan et al., 2001; Babcock et al., 2006). Beyond the obvious costs associated with treatments and death loss, BRD may have a greater economic impact due to losses in animal performance and carcass quality (Gardner et al., 1999; Roeber et al., 2001; Fulton et al., 2002). Therefore, finding better ways to classify BRD risk of cattle and predict and diagnose BRD events is important to the cattle industry.

Acute phase proteins (**APP**) are synthesized by the liver as a portion of the immune system's acute response to infection (Baumann and Gauldie, 1994). The APP haptoglobin (**Hp**) has been investigated as a biomarker for discrimination between acute and chronic infection in cattle (Horadagoda, et al., 1999) and monitoring response to antibiotic (Wittum et al., 1996). In newly received beef cattle, Hp concentrations of calves determined on arrival have been correlated with number of eventual treatments for signs of BRD (Carter et al., 2002; Berry et al., 2004). The objective of this experiment was to measure the concentration of Hp in the serum of calves with high risk of developing BRD upon arrival to the feedlot, allocate calves into pens according to

concentration, and evaluate the effect of arrival serum Hp concentration on animal performance and BRD morbidity and mortality during the receiving period.

MATERIALS AND METHODS

Experiment 1

Heifer calves (n = 360; BW = 241 ± 16.6 kg) of British and British × Continental breeding were assembled by Eastern Livestock at the West Kentucky Livestock Market (Marion, KY). Heifers were purchased at the West Kentucky Livestock Market and at other regional auction markets. As each truckload lot of 90 calves was assembled, heifers were processed prior to shipment. This included application of an individually numbered dangle tag in the left ear and administration, via the esophagus into the rumen, an electronic temperature monitoring bolus (SmartStock LLC, Pawnee, OK). In addition, a blood sample was collected via jugular venipuncture for serum harvest using evacuated tubes (Clott activator, Becton Dickinson Vacutainer Systems, Franklin Lakes, NJ). After blood collection, tubes were held on ice prior to and during transport to the laboratory for processing. Prior to shipment, heifers were maintained (approximately 4 to 48 h) in covered holding pens (loads 1, 2, and 4) or an open grass paddock (load 3) and given ad libitum access to long-stemmed hay and water prior to shipment. In separate lots of 180 (two truckloads/lot), heifers were shipped 957 km to the Willard Sparks Beef Research Center (**WSBRC**), Stillwater, OK. Calves were shipped on September 11 and 13, 2007, respectively, for a 63-d preconditioning study.

After arrival, heifers were allowed to rest for 5 to 6 h without access to feed or water prior to initial processing. This consisted of individually weighing, collection of an ear

notch for the detection of animals persistently infected with bovine viral diarrhea virus (**PI-BVDV**) using immunohistochemistry (Oklahoma Animal Disease Diagnostic Laboratory [**OADDL**], Stillwater, OK), and collection of a blood sample via jugular venipuncture for serum harvest (Clott activator, Bectin Dickinson Vacutainer Systems). After collection, blood samples were transported to the laboratory where serum was harvested and Hp was measured using a bovine ELISA test (Immunology Consultants Lab, Portland, OR). Blood tubes were allowed to clot at room temperature for approximately 3 h. Blood samples were then centrifuged at 3,000 × *g* at 4°C for 20 min. Samples were diluted 1:10,000 in tris buffered saline with tween 20, pH 4.0 (Sigma, St. Louis, MO) prior to analysis. The intra and inter assay coefficients of variation were less than 5%.

Heifers in Lot 1 were stratified by initial serum Hp concentration, based on the range and magnitude of values, along with considering the receiving pens available for the experiment (6 pens per arrival lot). Groups were **LOW** (< 1.0 µg/mL); **MED** (1.0 to 3.0 µg/mL); and **HIGH** (> 3.0 µg/mL) serum Hp concentration. Within Hp groups, heifers were stratified by arrival BW and randomly assigned into 1 of 2 pens per group (6 total pens for Lot 1). Thirty-three, 31, and 25 heifers were assigned to LOW, MED, and HIGH pens, respectively. For Lot 2, the same cut-off serum Hp concentrations were used as in Lot 1. However, more heifers were classified in HIGH than MED or LOW, and therefore 3 pens were used for HIGH (n = 34 or 35 heifers/pen), 2 for MED (n = 18 heifers/pen), and 1 for LOW (n = 20 heifers/pen). Three hundred thirty-seven heifers of the original 360 were used in the experiment. Heifers were excluded from the trial when they were PI-BVDV (n = 1), arrival serum samples were misidentified, or Hp analysis re-

runs were required that could not be completed prior to processing. Adjacent pens shared a fence-line automatic water basin, and care was taken to segregate Hp groups. LOW, MED, and HIGH groups were assigned to pens so that no LOW and HIGH calves were in adjacent pens or shared fenceline water basins. Whole blood was collected (Clott activator, Becton Dickinson) for serum Hp determination and heifers were weighed on d 7, 14, 21, and 63, and at the time of antimicrobial therapy for signs of BRD. One day prior to measuring BW and collecting blood on d 63 (d 62), 50% of the previous day's allotment of feed was delivered and water basins were turned off at 1700 h.

Experiment 2

Steer and bull calves (n = 416; body weight [**BW**] = 241 ± 24.4 kg), primarily British and British × Continental breeding, were purchased at the Oklahoma National Stockyards (Oklahoma City, OK) in two lots on September 17 (n = 128) and October 1 (n = 288), 2007, and shipped 107 km to the WSBRC for a 42-d preconditioning study. Upon arrival, calves were allowed to rest approximately 1 h without access to feed or water prior to initial processing. This included identification with a sequentially numbered dangle tag in the left ear, recording BW, and sex (steer or bull) determination. Additionally, an ear notch was collected for the determination of PI-BVDV calves (OADDL), and a whole blood sample (Clott activator, Bectin Dickinson) was collected from each calf by jugular venipuncture. Serum Hp concentration was determined as described above.

Similar to Exp. 1, steers were stratified by arrival serum Hp concentration. However, due to experience with similar calves (purchased at the same auction by the

same buyer) in previous years, we expected BRD morbidity to range from less than 10% to 50% of the calves requiring treatment. Combining this experience, the difference in sex, and the lower observed Hp concentrations, it was determined to use different Hp values for segregating the steers than was used for heifers in Exp. 1. Steers were grouped by not detectable (**ND**) and present (**PRES**) concentrations of Hp. Bulls (n = 27) were not included in the experiment due to the potential for dramatic increases in Hp as a part of the inflammatory response associated with surgical castration at processing. In addition, in Lot 2, 120 steers in each group were randomly selected for inclusion in the experiment due to pen space constraints. A total of 345 steers (initial BW = 240 ± 22.8 kg) were enrolled in the study. Six pens of ND (n = 23, 24, or 30 steers per pen) and 6 pens of PRES (n = 29 or 30 steers per pen) steers were used. Similar to Exp. 1, ND and PRES steers did not share fence-line water basins. Steers were weighed prior to feeding on d 7, 14, and 21, and on d 41, 50% of the previous day's allotment of feed was provided and water was removed at 1700 h prior to weighing on d 42.

Processing

The morning after arrival (d 0), calves were processed and sorted into their assigned pens. Processing consisted of recording individual BW, vaccination against infectious bovine rhinotracheitis (**IBR**), bovine virus diarrhea virus (**BVDV**; Types I and II), bovine parainfluenza-3 (**PI3**), and bovine respiratory synctial virus (**BRSV**; Pyramid 5, Fort Dodge Animal Health, Overland Park, KS), and clostridial pathogens (Vision 7, Intervet/Schering-Plough Animal Health, DeSoto, KS), and deworming with moxidectin (Cydectin, Fort Dodge Animal Health). Heifers in Exp. 1 were implanted with estradiol

and trenbalone acetate (Component TE-G, Vetlife, Overland Park, KS), but steers in Exp. 2 were not implanted. Calves were revaccinated against respiratory viral pathogens (Pyramid 5) on d 7.

Feeding Management

Receiving pens were open, 12.2 × 30.5 m with a 12.2 m fence-line concrete feed bunk. Both steers and heifers were fed twice daily, at 0700 and 1330 h, a 65% concentrate receiving/growing ration formulated to meet or exceed NRC (2000) nutrient requirements (Table 3.1). Feed bunk space per animal was 0.35 to 0.68 m for heifers in Exp. 1 and 0.41 to 0.53 m for steers in Exp. 2. Each morning prior to feeding, bunks were visually evaluated for the presence of refusals and feed delivery was adjusted so that less than 0.22 kg per calf remained each morning. Calves were challenged on intake every 2 to 4 d throughout the experiment. Between arrival and processing and for 7 days after processing, long-stemmed prairie hay was offered in the feed bunk as well as mixed ration. On d 0, 1.81 kg of prairie hay was offered per calf, and calves were offered less 0.45kg) hay daily as the consumption of mixed ration increased over time.

Assessment and Treatment of Morbid Animals

Each morning, calves were evaluated by trained personnel for signs of clinical BRD. The evaluation procedures used are standard to the facility and adapted from the DART system (Pharmacia Upjohn Animal Health, Kalamazoo, MI; Step et al., 2008). Specific subjective signs included evidence of depression (hanging head, sunken or glazed eyes, slow movement, arched back, difficulty in rising, knuckling or dragging toes when

walking, and stumbling); abnormal appetite (completely off feed, eating less than or with less aggression than penmates, lack of fill, or obvious BW loss); and respiratory signs (obvious labored breathing, extended head and neck, and noise when breathing). Based on the presence and seriousness of one or more of these sign(s), the evaluators assigned a severity score from 1 to 4, where 1 was mild, 2 moderate, 3 severe, and 4 moribund. Moribund calves would not rise from recumbency unassisted. When a severity score was assigned, calves were removed to the processing chute for rectal temperature measurement (GLA M-500; GLA Agricultural Electronics, San Luis Obispo, CA). Animals with rectal temperatures of 40°C or greater were administered antimicrobial therapy (treated). Additionally, when severity scores were 3 or 4, antimicrobial therapy was administered regardless of rectal temperature. When rectal temperature was < 40°C and severity score was < 3, no antimicrobial therapy was given. Following evaluation or treatment, all calves were returned to their home pens. Throughout the experiment, evaluators were blinded to arrival Hp concentration category and if antimicrobial treatments were administered.

A maximum of three antimicrobial therapies were allowed, and all doses were calculated by rounding the calf's current BW up to the nearest 11.3 kg. All pharmaceuticals were administered following Beef Quality Assurance Guidelines (NCBA, 2001) via a subcutaneous injection. The first treatment was administered in the left neck, and subsequent injections were given in alternating sides of the neck. When treatment criteria were met for a first treatment, 10 mg tilmicosin/kg BW (Micotil 300, Elanco Animal Health, Greenfield, IN) were administered. Following tilmicosin treatment, a 120-h moratorium was honored with the exception in the case of calves

assigned a severity score of 3 or 4, the moratorium was shortened to 72 h. When the appropriate post-treatment interval was honored and calves met treatment criteria a second time, 10 mg enrofloxacin/kg BW (Baytril 100, Bayer Animal Health, Shawnee, Mission, KS) were administered. Following a 48-h post-treatment interval, calves meeting treatment criteria received ceftiofur hydrochloride (Excenel RTU, Pfizer Animal Health, New York, NY). Ceftiufur therapy consisted of 2 doses (2.2 mg/kg BW) given 48 h apart.

Standards for defining chronically ill animals were used, and animals defined as chronically ill were removed from their home pens. Animals were not eligible for removal from their pens before d 21. In order to be defined as chronically ill, an animal must have been previously administered all three antimicrobial therapies according to protocol, and a 48-h post-treatment interval following the last dose of ceftiofur was honored. In addition, the calf must have been assigned a severity score of 3 or 4 on the day of removal, and a net loss of weight over at least a 21-d period was required. Any calf that died or required euthanasia had post-mortem examination at OADDL.

Finishing Performance and Carcass Data

Following preconditioning, heifers from Exp. 1 were allotted to one of two finishing studies. No association existed ($P > 0.10$) between preconditioning phase, Hp group allotment and finishing experiment, or treatment within finishing experiment. At the beginning of the finishing phase, heifers were implanted with trenbalone acetate and estradiol (Revalor-IH or Revalor-H, Intervet/Schering-Plough) and gradually adapted to and fed one of two 94% concentrate finishing diets. Diets were formulated to meet or

exceed NRC (2000) guidelines and contained 2.09 and 1.36 Mcal net energy for maintenance and gain, respectively, and 156 g of crude protein per kg of dry matter (**DM**). The diets were identical with the exception that dry corn distillers grains replaced wet corn distillers grains in one of the two diets. Initial and final BW were obtained prior to feeding at the start of the finishing period and one day prior to slaughter. Days on feed during the finishing phase were 139, 152, 174, or 189. Heifers were shipped 478 km to a commercial abattoir where trained personnel from Oklahoma State University collected carcass data including hot carcass weight (**HCW**), *longissimus* muscle (**LM**) area, marbling score, estimated percentage of internal fat (**KPH**), and 12th-rib fat thickness. Yield grade was calculated from HCW, LM area, 12^{th}-rib fat, and KPH, and quality grade was determined from marbling score and maturity data.

Lung Lesion Determination

The lungs from 189 heifers were evaluated in the plant at chain speed for the presence and severity of pulmonary lesions as evidence of prior bronchopneumonia. A scoring procedure based on that of Bryant et al. (1999) was used. Lungs were both visually observed and briefly palpated. For each side (right and left) the presence and severity (0, 1, 2, 3) of lesions were recorded, along with the absence or presence (0, 1) of interlobular adhesions or missing lobes indicating thoracic adhesions. Overall evidence of bronchopneumonia (0, 1) was based on the presence of a lesion, adhesion, or missing lobe for each side and the overall lung.

Statistical Analysis

Data from each experiment were analyzed separately as randomized complete block designs using the MIXED procedure of SAS (SAS Institute, Cary, NC). For all preconditioning phase performance variables and subjective and objective signs of morbidity, pen was the experimental unit. For performance data, the model contained arrival Hp concentration group as a fixed effect and arrival lot was considered a random effect. Similarly, serum Hp concentrations measured at the time of treatment for signs of BRD were averaged by pen and analyzed as above. Haptoglobin concentrations from the samples collected prior to shipment (d -2) and on days 0, 7, 14, 21, 42, and 63 were analyzed as a randomized complete block design with repeated measures using the MIXED procedure of SAS. Individual animal, nested within pen, was considered the experimental unit. The model statement contained the fixed effects of Hp concentration, day, the Hp group × day interaction, and the random statement included arrival lot, pen, and animal nested within pen. The model was subjected to multiple covariance structures and the best fit model was selected to contain the covariance structure that yielded the smaller Akaike and Schwarz's Bayesian criterion based on their – 2 res log-likelihood. A first order ante-dependence covariance structure was used for the analysis. Since the Hp group × day interaction was significant ($P < 0.001$), interaction Least squares means were separated for each day using the pdiff option for the LSmeans statement in SAS.

Non-parametric data (morbidity and mortality rates) were analyzed as binomially distributed using the GLIMMIX procedure of SAS using the mixed model described above. The logit link function was assumed. Frequencies were estimated using the lsmeans statement and ilink option, and odds ratios, comparing MED or HIGH to LOW

in Exp. 1 or PRES to ND in Exp 2. For Exp. 1, orthogonal polynomial contrasts were used to test the linear and quadratic effects of increasing arrival serum Hp concentration group.

Finishing phase BW, ADG, carcass characteristics, and the presence of incidence of lung lesions were analyzed as a randomized complete block design with SAS. Individual heifer was considered the experimental unit. Haptoglobin concentration group was the fixed effect. The significance of the interaction of Hp group with finishing trial was tested and shown to be insignificant ($P > 0.20$) for all variables. Therefore, finishing trial and finishing treatment nested within trial were included in the random statement. Continuous variables were analyzed using the MIXED procedure while non-parametric variables were analyzed using the GLIMMIX procedure. Orthogonal polynomial contrasts were used to test the linear and quadratic effects of increasing arrival serum Hp. For all analyses, denominator degrees of freedom were corrected using the Kenward-Rogers option. Least squares means were considered different with $P \leq 0.05$ and tendencies when $0.05 < P \leq 0.10$.

RESULTS

Experiment 1

Serum Hp Concentration. The mean serum Hp concentration for all heifers upon arrival was 4.22 ± 3.78 µg/mL. After allocation to the respective arrival Hp concentration groups, there were both linear and quadratic increases ($P < 0.001$) in serum Hp from LOW to HIGH (Table 3.2). When considered across the entire experiment, there was a significant group × day interaction and Hp group and time effects ($P < 0.001$)

for serum Hp concentration. Interaction Least squares means are presented in Table 3.2 and Figure 3.1. Prior to shipment from the order buyer facility, concentrations were lower than upon arrival ($P < 0.001$) and greater for HIGH heifers than LOW and MED. Peak Hp concentration occurred at arrival for MED and HIGH groups and on d 7 for LOW heifers. By d 7, serum Hp concentrations were similar ($P = 0.04$) for all three groups. While average Hp concentrations decreased from d 14 to 63, they tended ($P \leq 0.09$) to remain greater for HIGH than LOW and MED on d 14 and greater ($P \leq 0.09$) than LOW on d 21 and 63.

Performance. At arrival, there was a quadratic effect ($P < 0.001$) of serum Hp concentration on BW with MED heifers weighing less than LOW and HIGH (Table 3.3). However, by d 7, all three groups had similar ($P \geq 0.25$) BW, and no differences in BW ($P \geq 0.12$) were observed throughout the duration of the experiment. Both linear ($P = 0.04$) and quadratic ($P = 0.02$) effects of increasing arrival Hp concentration were observed in ADG from d 0 to 7. In addition, average daily gain (**ADG**) tended to be decreased linearly ($P = 0.08$) as arrival Hp concentration increased from d 8 to 14. For days 1 to 21, 22 to 42, and 43 to 63, and for the overall experiment, ADG was similar ($P \geq 0.16$) for all heifers. Dry matter intake (**DMI**), expressed both as kg/d and as a percent of average BW, decreased linearly ($P \leq 0.03$) as arrival Hp concentration increased from LOW to HIGH from d 1 to 7, 8 to 14, 15 to 21, and 1 to 21. The ratio of ADG to DMI (**G:F**) was similar ($P \geq 0.80$) across the 63-d receiving period. However, during the first week of the experiment, MED heifers were more (quadratic, $P = 0.04$) efficient utilizers of intake for gain than LOW and HIGH heifers.

Health. Overall BRD morbidity was 57.6% and mortality was 8.6%. Total morbidity was linearly increased ($P = 0.05$) as arrival Hp concentration increased (Table 3.4). The odds ratios, when compared to LOW heifers, were 1.48 and 2.05 for MED and HIGH, respectively. However, there were no differences ($P \geq 0.37$) in the distribution of heifers that required only 1 or 2 treatments for BRD. More MED and HIGH heifers required three treatments than LOW (linear, quadratic, $P \leq 0.05$), but no differences ($P \geq 0.37$) in the number of heifers that were considered chronically ill were observed. The odds of MED and HIGH heifers requiring three treatments were 188 and 336% greater than LOW heifers. Though numerically greater for MED and HIGH than LOW, there were no statistical differences ($P \geq 0.46$) in total mortality or case fatality rates.

The number of days on feed to first treatment was similar ($P \geq 0.24$) among all Hp groups (Table 3.5). However, days on feed to second treatment tended to be decreased (linear, $P = 0.07$) for HIGH (10.5) compared with LOW (13.0) and MED (13.6). Similarly, days on feed to third treatment was linearly decreased ($P = 0.05$) as arrival Hp concentration increased. When considering measured parameters of heifers requiring treatment for BRD, there was no difference ($P \geq 0.23$) in serum Hp concentrations between LOW, MED, and HIGH heifers at the time of the first, second, or third treatment. Rectal temperature was 40.97°C for LOW, 41.15°C for MED, and 41.20°C (quadratic, $P = 0.03$) for HIGH heifers at the time of first treatment, but was similar ($P \geq 0.39$) at the time of second and third treatments for BRD. Subjective severity score was similar ($P \geq 0.69$) among groups when pulled for a first treatment but tended to be linearly increased ($P = 0.10$) or decreased ($P = 0.06$) at the times of second and third treatments, respectively.

Finishing Phase. There was a significant Hp group × finishing trial interaction (P = 0.03) for total days on feed (Table 3.6). This occurred because in one finishing trial, LOW heifers were fed longer (213 d) compared to MED (208 d) and HIGH (209 days). One trial resulted in heifers being fed 26 d longer (P = 0.004) than the other, but no other differences (P = 0.14) in Hp group for days on feed were detected. No other Hp group × finishing trial differences ($P \geq 0.25$) were seen in any other finishing phase performance or carcass variables (data not shown). Because of the lack of association ($P > 0.10$) between the distribution of heifers in Hp concentration group and finishing trial and treatment within trial, the data were pooled. No differences ($P \geq 0.11$) in any finishing phase growth or carcass variables among Hp groups were detected.

Lung Lesions. No differences ($P \geq 0.29$) were detected in the proportion of heifers that had any evidence of pulmonary damage, interlobular adhesions, or missing lobes (Table 3.6). However, MED had a greater (quadratic, P = 0.03) proportion of heifers with lesions classified as severe followed by LOW and HIGH.

Experiment 2

Serum Haptoglobin Concentration. Overall serum Hp concentration measured upon arrival was 0.238 ± 0.504 µg/mL. In the PRES group, arrival Hp was (0.451 ± 0.057 µg/100; $P < 0.001$; Table 3.7).

Performance. Steers with detectable serum Hp upon arrival weighed less ($P \leq$ 0.009) on d 0, 7, 14, 21, and 42 than ND (Table 3.7). For the first 7 days on trial, both groups lost BW, with the PRES (-0.78 kg/d) having lower ADG than ND (-0.27 kg/d; P = 0.04). Both interval (d 8 to 14, 15 to 21, 21 to 42, and 1 to 21) and overall ADG was

similar ($P \geq 0.28$) between the two groups for the remainder of the trial. Dry matter intake was lower ($P \leq 0.04$) for PRES than ND from d 1 to 7, 8 to 14, 22 to 21, 1 to 21, and 1 to 42. When expressed as a % of average BW, DMI was less ($P = 0.05$) for PRES than ND from d 8 to 14 and tended ($P = 0.06$) to be decreased by 0.14 and 0.15 percentage points from days 22 to 42 and 1 to 42, respectively. Aside from the first week, when steers lost weight, the ratio of G:F was similar ($P \geq 0.29$) between ND and PRES steers for the duration of the study. The ratio of G:F was -0.080 and -0.275 for ND and PRES steers from days 1 to 7 ($P = 0.04$).

Health. Overall morbidity was not statistically different ($P = 0.17$) for ND (37.7%) vs. PRES (57.3%; Table 3.8). Similarly, the number of steers requiring only 1 or only 2 BRD treatments was similar ($P \geq 0.44$) among Hp groups, but PRES steers had more ($P = 0.03$) steers that required 3 BRD treatments (13.56%) than ND (5.43%). No difference ($P \geq 0.24$) in the number of steers classified as chronically ill or that died was detected.

Steers with detectable Hp present at arrival were treated the first time approximately 3 d sooner ($P = 0.008$) than were ND steers (5.4 vs. 8.5 days on feed). The days on feed to third treatment also tended to be less for PRES steers than ND (19.2 vs. 25.9; $P = 0.08$). Rectal temperature was not different ($P = 0.92$) when steers were treated the first time, and was greater ($P = 0.04$) for PRES than ND for at the second treatment, but less ($P = 0.04$) at the third treatment. Subjective severity score was greater ($P = 0.03$) when steers were pulled for their first (1.3 vs. 1.5) and third (1.3 vs. 2.1) treatments for PRES than ND, but was similar ($P = 0.31$) for both groups when steers were pulled for their second treatments.

DISCUSSION

In cattle, Hp has been the most widely studied APP (Horadagoda et al., 1999), and has been shown to increase rapidly in response to multiple pathogens from both natural (Wittum et al., 1996; Horadagoda et al., 1999) and experimental (Conner et al., 1989; Burciaga-Robles, 2009) exposure. Haptoglobin functions to bind hemoglobin, released into the blood as a result of red blood cell hemolysis, preventing utilization by bacteria (Wassell, 2000), and is produced by hepatocytes after stimulation with pro-inflammatory cytokines such as interleukin-I (IL-1) and tumor necrosis factor-α (TNF-α) as a part of the acute phase response (Baumann and Gauldie, 1994). Exposure to the viral BRD pathogen BVDV alone did not result in increased serum Hp concentration (Burciaga-Robles, 2009). However, intratracheal challenge with the bacterial pathogen *Mannheimia haemolytica* (MH) resulted in elevated serum Hp concentration 18 h after MH exposure, which remained greater than controls 96 h after challenge. While both viral and bacterial pathogens increased pro-inflammatory cytokine production, challenge with both pathogens resulted in the greatest concentration of IL-1 and TNF-α (Burciaga-Robles, 2009). This suggests that viral and bacterial pathogens have an additive effect, with increased immune response and possibly clinical disease severity resulting from the combination of both types of pathogens.

The BRD complex has a multi-factorial etiology and multiple predisposing factors (Duff and Galyean, 2007). Risk-factors that affect BRD incidence include prenatatal and preweaning nutrition and health management and postweaning factors, which include duration of the weaning period prior to shipment, transportation and market stress, commingling, and nutrition and health management (Duff and Galyean, 2007; Step et al.,

2008). The heifer calves in Exp. 1 were classified upon arrival as having high-risk of developing BRD because they possessed several of these risk-factors including: short duration of weaning prior to shipment; high marketing stress with at least 60% of the animals being routed through separate auction markets and order-buyer facilities; commingling; and long-transport distance. The combination of these stressors and likely pathogen exposure during marketing resulted in increased serum Hp concentration measured after arrival compared to pre-shipment. In cattle with fewer overall risk factors (adequate health and nutrition management; 28-d weaning period prior to shipment; not commingled), Hp was increased from pre-shipment levels after an 1,800 km transport, peaked near 3 times pre-shipment values 24 h after arrival, and remained elevated through 72 h after arrival (Qiu et al., 2007). Transportation, but not commingling was shown to increase serum Hp in one study (Arthington et al., 2003). In calves with similar pre-weaning management, Arthington et al. (2005, 2008) reported calves weaned prior to shipment (84 days of age) had lower Hp after arrival at the feedlot than those weaned at shipment (300 days of age). Serum Hp concentration measured upon arrival was similar for commingled calves sourced at an auction with unknown prior management and calves sourced from one ranch and weaned the day of shipment to the feedlot (Step et al., 2008). However, steers from the same ranch of origin who had been weaned 45 d prior to shipment or weaned and vaccinated 45 d prior to shipment had approximately 33% the concentration of Hp upon arrival compared with auction market calves or calves shipped immediately at weaning. Serum Hp was measured in the present study through d 63, longer than most published reports. Serum Hp concentrations, though decreased in magnitude, remained greater in HIGH and MED compared with LOW heifers on d 14,

21, and 63. Similarly, Hp was elevated compared to pre-shipping values on d 5 and 17 or d 7 (Exp. 1 and 2, respectively) in the experiment of Arthington et al. (2003). Burciaga-Robles (2009) measured elevated Hp through 96 h in steers challenged with BVDV and MH but with no transport stress. Young et al. (1996) measured serum Hp in feedlot cattle 0, 40, and 65 days on feed, and reported that 60% of calves had detectable concentrations in at least one of the three samples. However, change in Hp concentrations in the same animals over time were not evaluated. Berry et al. (2004) observed the greatest average Hp concentration on d 7, although by d 14 and 28, concentrations had dropped below d 0. While the acute-phase response is transient, and APP concentrations typically decrease to baseline within days of peaking (Peterson et al., 2004). In the present experiment, the higher mean Hp values maintained in MED and HIGH heifers, along with increased serum Hp in the LOW group compared with arrival concentration, could be associated with transport stress, clinical or subclinical BRD, or with an acute phase response associated with adaptation to a higher-concentrate diet (Ametaj et al., 2009). Within a pen, different animals could be in all phases of an acute phase response, induced by different factors, so while concentrations may be decreasing in some animals, they may be peaking, or just starting to increase in others.

Serum Hp concentration in the feedlot has also been negatively correlated with ADG in calves that were weaned at shipment but not in those that were pre-weaned (Arthington et al., 2005). Unlike the present experiment, BRD morbidity was not observed in the Arthington et al. (2005) experiment, suggesting that those animals were suffering from a sub-acute infection and related acute phase response, or the acute phase response induced by stress of normal management in healthy calves had sufficient effects on nutrient

metabolism and animal growth to be similar to the response associated with clinical disease (Le Floc'h et al., 2004; Burciaga-Robles, 2009).

In the present experiments, ADG was decreased as Hp increased during the early portion of the feeding period, although this decrease in ADG tended to extend over the entire receiving period in Exp. 1. Bovine respiratory disease morbidity was prevalent in these cattle during the first days on feed with average days on feed to first treatment occurring by d 9 in all groups. Therefore, any decrease in animal performance due to arrival Hp concentration cannot be separated from an acute phase response caused by stress of normal management vs. an immune response in clinically ill animals. The lower initial BW in steers in Exp. 2 with elevated Hp concentration upon arrival may be the result of greater sensitivity to stress and multiple acute phase responses throughout the calf's life prior to feedlot arrival.

Dry matter intake associated with the concentration of Hp measured upon arrival was decreased when expressed in kg/d or as a percent of average BW throughout the entire experiment. While other reports correlating Hp concentration and DMI are unavailable, it is well established that newly received calves have decreased DMI after arrival (Hutcheson and Cole, 1986) and NRC (2000) recommended that nutrients be concentrated in the diets of newly received animals so that absolute animal requirements are met. Hutcheson and Cole (1986), in a summary of 18 experiments, reported that only 83.4 and 94.6% of morbid and healthy calves had consumed any feed by d 7 after arrival, and measured DMI of morbid calves at 58, 68, and 88% of healthy calves during the first week, 4 weeks, and 8 weeks, respectively. Morbid calves also visited the feedbunk fewer

times and spent less total time at the feedbunk daily (Sowell et al., 1999; Buhman et al., 2001).

In feedlot cattle, Hp measured on arrival has been positively correlated with the number of times the animal would receive antimicrobial treatment for BRD during the receiving period (Carter et al., 2001; Berry et al., 2004). Other studies have measured increased Hp concentrations in calves that were subsequently treated, but could not correlate concentration to number of treatments (Step et al., 2008). In the experiment of Step et al. (2008), steers that were sourced at auction markets or weaned and shipped from a single ranch on the day of weaning had greater arrival Hp than steers that were weaned 45 d prior to shipment. Total morbidity in pre-weaned steers was 25% or less than that of auction origin and newly weaned steers. However, Hp concentration cannot be separated from weaning management in predicting morbidity. Young et al. (1996) measured Hp on d 0, 40, and 65 after placement in the feedlot and saw an association between Hp measured on d 40 or 65 and subsequent BRD development. However, they reported that Hp had low ability to predict BRD episodes within 10 d of measurement. In Exp. 1, a linear increase in total morbidity rate was observed as arrival Hp went from LOW to HIGH. This resulted in MED heifers having 48% greater and HIGH heifers having 105% greater odds of being treated at least once than LOW. This difference was because more heifers in the MED and HIGH groups required three treatments or were ultimately classified as chronically ill compared to LOW. This was repeated in Exp. 2, in which steers with measurable Hp had 304% higher odds of being treated 3 times than did ND steers. The steers in Exp. 2 were considered to be of lower risk than heifers in Exp. 1. Although the steers were of auction market origin, they were not moved through an

order buyer facility after purchase and the distance transported was 10% of the heifers. In addition, steers were purchased in the same markets and by the same buyer as the cattle of Holland (2006), who observed no difference in arrival serum Hp concentration between calves that were treated 0, 1, or > 1 times for signs of BRD.

At the time of BRD treatment no difference in Hp concentration existed between the three groups, concurring with Step et al. (2008). The decreased days on feed to first treatment by PRES compared with ND in Exp. 2 indicates an active disease may have been involved in PRES steers on arrival. In both experiments, increasing Hp resulted in fewer days on feed at the second and third treatments. A decrease in Hp concentration after antimicrobial treatment for respiratory signs has been reported (Wittum et al., 1996; Berry et al., 2004). Though Hp at the time of treatment was not different, increased Hp at arrival might indicate a more severe infection and predict a less effective antimicrobial response, or a more chronic condition (Alsemgeest, 1994; Haradagoda et al., 1999). Prophylactic medication, given via feed or injection to clinically healthy animals has been shown to decrease BRD morbidity and mortality (Duff and Galyean, 2007). Possibly, earlier intervention targeted only to cattle with higher Hp concentrations at arrival could reduce the impacts of BRD on morbidity, mortality, and performance in those animals and decrease the administration of antibiotics to animals that are not ill. The inconsistencies observed between arrival group and rectal temperature in both experiments indicates that separate mechanisms exist for inducing fever and the APP response after pathogen challenge (Burciaga-Robles, 2009). Similarly, in Exp. 2 steers that had measureable Hp present on arrival were subjectively judged to have worse clinical condition when pulled and treated at the first and third treatment, but in Exp. 1

heifers in the LOW group tended to have higher severity scores than HIGH with MED intermediate. This could be due to the longer days on feed at the third treatment for LOW heifers than MED and HIGH, when sick animals could appear relatively worse than they would have when the entire group had fewer days on feed. Though not statistically different, the odds ratios for total mortality and case fatality rates for MED and HIGH compared to LOW and the fact that no BRD mortalities occurred also support the possibility that animals arriving with higher Hp concentrations have a more chronic disease state, and antimicrobial treatment when clinical signs become evident would be less effective. Similarly, Young et al. (1996) observed a positive association between Hp and the presence of lung lesions at slaughter. However, the lack of association between higher Hp concentration and lung lesions at slaughter in the present study might indicate that the disease was more severe in this case. The more severely ill cattle reported by Young et al. (1996) may have survived, but with greater lung damage, while the severe cases in the present experiment died. Moreover, while the percentage of chronics was numerically greater for HIGH and MED than LOW, the lower numerical rate of chronics as a percent of calves treated three times, might suggest that more animals died prior to the third treatment or chronic determination. The relatively high rate of animals treated multiple times, chronically ill animals, and BRD mortalities in all three Hp groups in Exp. 1, suggest that, while serum Hp at arrival may be valuable for predicting subsequent BRD cases and severity of those cases, the response is variable. However, increased serum Hp concentration measured upon arrival was associated with increased risk of multiple treatments for signs of BRD, and using Hp to predict or evaluate risk of BRD remains possible. More appropriate cut-off values for arrival serum Hp should be

determined, and management strategies to reduce the effect of BRD in calves with differing arrival Hp concentrations, such as targeted prophylaxis, should be addressed.

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Table 3.1. Ingredient and nutrient composition of the receiving diet.

Item	Concentration
Dry rolled corn	45.0
Wet corn distillers grains w/solubles	15.0
Ground alfalfa hay	17.5
Ground prairie hay	17.5
B-157[1]	5.0
Nutrient composition[3]	
Dry matter, %	72.3
Crude protein, %	14.1
NDF, %	30.7
ADF, %	18.9
Ca, %	0.75
P, %	0.39

[1]B-157 pelleted supplement contained (% of dry matter): ground corn, 69.6%; calcium carbonate, 20.0%; salt, 7.5%; urea, 5.83%; magnesium oxide, 2.0%; zinc sulfate, 0.300%; copper sulfate, 0.140%; manganous oxide, 0.100%; vitamin A (30,000 IU/g), 0.064%; vitamin E (50%), 0.044; Rumensin 80 (Elanco Animal Health, Indianapolis, IN), 0.25%.

[3]All values except dry matter calculated based on NRC (2000) values and expressed on a DM basis.

Table 3.2 Serum haptoglobin (µg/mL; Exp. 1).

	Arrival Haptoglobin Group[1]				Contrast[2]	
Day	LOW	MED	HIGH	SEM[3]	L	Q
d -2[4]	0.18	0.08	0.34	0.073	0.12	0.05
d 0	0.60	1.90	7.80	0.203	<0.001	<0.001
d 7	1.87	1.95	2.32	0.234	0.16	0.57
d 14	1.72	1.66	2.30	0.274	0.09	0.26
d 21	0.89	1.37	1.55	0.220	0.02	0.58
d 42	0.41	0.73	0.69	0.161	0.18	0.31
d 63	0.02	0.06	0.21	0.089	0.09	0.58

[1]Heifers grouped based on serum Hp concentration measured on d 0. LOW, ≤ 1.0 µg/mL; MED, 1.0 to 3.0 µg mL; HIGH > 3.0 µg/ mL.

[2]Significance for polynomial contrasts for Hp group within each day. L = linear, Q = quadratic. Hp group × day ($P < 0.001$).

[3]Standard error of the Least squares means (n = 3 pens for LOW; 4 pens for MED; 5 pens for HIGH). The greatest SEM is shown.

[4]Samples collected prior to shipping heifers from the order buyer facility, Marion, KY, to Stillwater, OK.

Table 3.3. Effects of arrival serum Hp concentration group on BW, ADG, DMI, and G:F of newly received beef heifers in Exp. 1.

	Arrival Haptoglobin Group[1]				Contrast[2]	
Item	LOW	MED	HIGH	SEM[3]	L	Q
BW, kg						
d 0	242	239	242	0.59	0.27	<0.001
d 7	246	244	244	1.24	0.25	0.78
d 14	250	247	245	5.46	0.12	0.89
d 21	259	255	256	4.87	0.39	0.56
d 42	286	287	286	4.21	0.97	0.86
d 63	322	316	314	5.14	0.16	0.77
ADG, kg/d						
d 1 to 7	0.58	0.77	0.17	0.134	0.05	0.02
d 8 to 14	0.70	0.46	0.22	0.784	0.08	0.98
d 15 to 21	1.21	1.15	1.47	0.185	0.28	0.33
d 1 to 21	0.81	0.80	0.63	0.224	0.19	0.49
d 22 to 42	1.33	1.47	1.42	0.143	0.60	0.47
d 43 to 63	1.69	1.42	1.33	0.181	0.16	0.65
d 1 to 63	1.27	1.23	1.13	0.078	0.09	0.64
DMI, kg/d						
d 1 to 7	3.37	3.30	2.74	0.303	0.004	0.10
d 8 to 14	4.18	3.80	3.41	0.471	0.02	0.99
d 15 to 21	5.48	4.98	4.70	0.519	0.03	0.67
d 1 to 21	4.33	4.02	3.61	0.420	0.01	0.79
d 22 to 42	7.32	7.19	6.69	0.687	0.11	0.55
d 43 to 63	8.24	8.30	7.73	0.418	0.30	0.41
d 1 to 63	6.58	6.39	5.89	0.496	0.06	0.56
DMI, % of BW[4]						
d 1 to 7	1.38	1.36	1.13	0.124	0.003	0.06
d 8 to 14	1.69	1.54	1.39	0.174	0.02	0.99
d 15 to 21	2.15	1.97	1.87	0.159	0.02	0.66
d 1 to 21	1.73	1.62	1.45	0.153	0.006	0.60
d 22 to 42	2.69	2.65	2.47	0.216	0.08	0.47
d 43 to 63	2.71	2.75	2.58	0.107	0.33	0.32
d 1 to 63	2.34	2.30	2.12	0.159	0.05	0.38
G:F						
d 1 to 7	0.169	0.235	0.061	0.049	0.12	0.04
d 8 to 14	0.151	0.092	0.047	0.195	0.05	0.85
d 15 to 21	0.217	0.238	0.316	0.050	0.02	0.36

d 1 to 21	0.181	0.193	0.173	0.038	0.73	0.46
d 22 to 42	0.182	0.212	0.214	0.035	0.25	0.54
d 43 to 63	0.206	0.170	0.174	0.038	0.73	0.46
d 1 to 63	0.194	0.193	0.192	0.008	0.80	0.99

[1]Heifers grouped based on serum Hp concentration measured on d 0. LOW, ≤ 1.0 µg/mL; MED, 1.0 to 3.0 µg mL; HIGH > 3.0 µg/ mL.

[2]Significance for polynomial contrasts for Hp group. L = linear, Q = quadratic.

[3]Standard error of the Least squares means (n = 3 pens for LOW; 4 pens for MED; 5 pens for HIGH). The greatest SEM is shown.

[4](DMI/Average BW for the period) × 100.

Table 3.4. Morbidity and mortality of newly received heifers allotted to pens according to serum haptoglobin concentration at arrival in Exp. 1.

	Arrival Haptoglobin Group[1]				Contrast[2]		Odds Ratio[3]	
Item	LOW	MED	HIGH	SEM[4]	L	Q	MED	HIGH
Morbidity, %[5]								
Total	48.26	57.99	65.65	11.75	0.05	0.90	1.48	2.05
Retreats	47.07	57.04	62.34	8.70	0.17	0.79	1.49	1.86
Third Pulls	10.43	25.09	28.12	8.82	0.01	0.16	2.88	3.36
T1	29.40	25.66	32.45	5.74	0.70	0.37	0.83	1.15
T2	10.47	11.22	11.11	3.19	0.90	0.93	1.08	1.07
T3	5.13	10.15	16.27	7.79	0.03	0.81	2.09	3.60
Chronic	1.84	4.42	3.49	2.95	0.49	0.39	2.46	1.93
C, % of Third	18.18	18.52	12.50	7.48	0.71	0.78	1.02	0.64
Mortality, %[6]								
Total	5.81	9.18	9.80	2.92	0.48	0.72	1.64	1.76
CFR	8.69	13.56	15.79	4.45	0.46	0.80	1.65	1.96

[1]Heifers grouped based on serum Hp concentration measured on d 0. LOW, ≤ 1.0 µg/mL; MED, 1.0 to 3.0 µg mL; HIGH > 3.0 µg/mL.

[2]Significance for polynomial contrasts for Hp group. L = linear, Q = quadratic.

[3]Odds ratios for MED:LOW and HIGH:LOW.

[4]Standard error of the Least squares means (n = 3 pens for LOW; 4 pens for MED; 5 pens for HIGH). The greatest SEM is shown.

[5]Total = percentage of heifers treated at least one or more times for BRD; Retreats = numbers of heifers requiring 2 or more BRD treatments, as a percent of those that required one treatment; Third pulls = percent of heifers that required three treatments for BRD; T1, T2, T3 = the percent of heifers that required 1, 2, or 3 total treatmenst (excluding those defined as chronically ill); Chronic = percent t of heifers defined as chronically ill according to protocol; C, % of third = the percent of chronically ill heifers expressed as a percent of those treated 3 times.

[6]Mortality: Total = percent of deaths attributed to BRD; CFR = number of heifers treated at least one time for BRD, expressed as a percent of Total Morbidity.

Table 3.5 Days on trial and subjective severity score, rectal temperature, and serum haptoglobin concentrations of heifers at the time of treatment for BRD in Exp. 1.

	Arrival Haptoglobin Group[1]				Contrast[2]	
Item	LOW	MED	HIGH	SEM[3]	L	Q
First Treatment[4]						
Day	5.8	6.7	5.1	0.93	0.55	0.24
Severity	1.4	1.4	1.4	0.15	0.69	0.69
Temperature	40.97	41.15	41.20	0.072	0.03	0.46
Haptoglobin	3.17	3.18	3.50	0.365	0.49	0.69
Second Treatment[4]						
Day	13.0	13.6	10.5	0.96	0.07	0.11
Severity	1.6	1.9	2.0	0.32	0.10	0.68
Temperature	40.98	40.95	40.97	0.107	0.94	0.85
Haptoglobin	3.37	3.13	3.24	0.510	0.85	0.76
Third Treatment[4]						
Day	24.1	17.5	17.2	2.49	0.05	0.27
Severity	2.0	1.8	1.7	0.14	0.06	0.61
Temperature	40.70	40.84	40.72	0.149	0.95	0.39
Haptoglobin	3.10	2.42	3.57	0.994	0.70	0.23
Day Removed[5]	39.3	25.7	29.9	5.84	0.23	0.19
Day Dead[6]	26.3	27.7	35.8	8.33	0.40	0.75

[1]Heifers grouped based on serum Hp concentration measured on d 0. LOW, ≤ 1.0 µg/mL; MED, 1.0 to 3.0 µg mL; HIGH > 3.0 µg/ mL.

[2]Significance for polynomial contrasts for Hp group within each day. L = linear, Q = quadratic. Hp group × day ($P < 0.001$).

[3]Standard error of the Least squares means (n = 3 pens for LOW; 4 pens for MED; 5 pens for HIGH). The greatest SEM is shown.

[4]Day of treatment; Severity score (1 = mild, 2 = moderate, 3 = severe, 4 = moribund); Rectal temperature, °C; serum haptoglobin concentration, µg/mL at the time of the first, second, or third treatment for BRD.

[5]Day on trial when chronic heifers were removed from their home pens.

[6]Day on trial at the time of death.

Table 3.6. Finishing BW, ADG, carcass characteristics, and incidence of pulmonary lesions of heifers allotted to pens according to serum haptoglobin concentration feedlot arrival (Exp. 1).

	Arrival Haptoglobin Group[1]				Contrast[2]	
Item	LOW	MED	HIGH	SEM[3]	L	Q
DOF[4]	224	222	222	3.24	0.15	0.14
Initial BW, kg	289	294	291	11.48	0.58	0.21
Final BW, kg	517	527	522	6.85	0.53	0.27
ADG, kg/d	1.41	1.45	1.44	0.040	0.50	0.52
HCW, kg	330	334	333	4.37	0.58	0.59
Dress., %	63.79	63.26	63.70	0.301	0.79	0.11
LM area, cm^2	77.6	79.0	78.7	1.274	0.44	0.51
FT, cm	1.27	1.37	1.33	0.057	0.46	0.28
KPH, %	1.88	1.89	1.95	0.059	0.33	0.63
YG	3.06	3.10	3.09	0.097	0.78	0.81
Marbling[5]	446	444	438	12.46	0.59	0.86
Lung Lesions[6]						
Overall	63.80	61.31	60.83	8.02	0.76	0.91
Severe	17.26	27.74	11.23	6.98	0.35	0.03
Adhesion	18.83	20.95	27.57	6.30	0.29	0.78
Missing	10.31	12.62	12.71	6.19	0.78	0.87

[1]Heifers grouped based on serum Hp concentration measured on d 0. LOW, ≤ 1.0 µg/mL; MED, 1.0 to 3.0 µg mL; HIGH > 3.0 µg/ mL.

[2]Significance for polynomial contrasts for Hp group within each day.

[3]Standard error of the Least squares means (n = 3 pens for LOW; 4 pens for MED; 5 pens for HIGH). The greatest SEM is shown.

[4]Total days on feed from arrival to slaughter. Hp group × finishing trial ($P = 0.03$). In finishing trial one total days on feed were: LOW, 213; MED = 208; HIGH = 209, and in trial two, total days on feed were: LOW, 235; MED, 236; HIGH, 237.

[5]300 = slight 0, 400 = small 0; 500 = modest 0.

[6]Lung lesions observed on 189 heifers at slaughter. Overall, the percent of heifers that had lungs with at least one of the following: lesion (score 1, 2, or 3), interlobular adhesion, or missing lobe; Severe, the percent of heifers that had lungs with lesions scored 2 or 3; Adhesion, at least one interlobular adhesion; Missing, substantial tissue missing.

Table 3.7. Receiving period performance of steers allotted to pens according to serum haptoglobin concentration upon arrival in Exp. 2.

	Arrival Haptoglobin Group[1]			
Item	ND	PRES	SEM[2]	Prob.[3]
Haptoglobin, µg/mL[4]	-0.008	0.4512	0.057	<0.001
BW, kg				
d 0	244	235	1.22	<0.001
d 7	242	230	1.28	<0.001
d 14	249	237	2.32	0.003
d 21	256	245	3.42	0.009
d 42	278	266	2.05	0.003
ADG, kg/d				
d 1 to 7	-0.27	-0.78	0.249	0.04
d 8 to 14	1.00	0.95	0.289	0.89
d 15 to 21	0.97	1.24	0.331	0.36
d 1 to 21	0.57	0.47	0.120	0.44
d 22 to 42	1.04	1.02	0.111	0.78
d 1 to 42	0.80	0.74	0.037	0.28
DMI, kg/d				
d 1 to 7	3.49	2.99	0.186	0.04
d 8 to 14	4.79	4.17	0.232	0.01
d 15 to 21	5.38	4.98	0.421	0.15
d 1 to 21	4.55	4.04	0.274	0.03
d 22 to 42	7.02	6.38	0.130	0.006
d 1 to 42	5.78	5.19	0.189	0.01
DMI, % of BW[5]				
d 1 to 7	1.43	1.29	0.076	0.13
d 8 to 14	1.95	1.79	0.091	0.05
d 15 to 21	2.13	2.07	0.152	0.55
d 1 to 21	2.22	2.07	0.065	0.06
d 22 to 42	2.63	2.49	0.045	0.06
d 1 to 42	2.22	2.07	0.065	0.06
G:F				
d 1 to 7	-0.080	-0.275	0.081	0.04
d 8 to 14	0.204	0.233	0.055	0.69
d 15 to 21	0.183	0.241	0.052	0.29
d 1 to 21	0.124	0.114	0.021	0.72
d 22 to 42	0.149	0.160	0.018	0.36
d 1 to 42	0.138	0.141	0.007	0.70

[1]Steers grouped based on serum Hp concentration measured on d 0. ND, not detectable; PRES, measurable concentration.

[2]Standard error of the least squares means (n = 6 pens/group).

[3]Observed significance of the difference between treatment means.

[4]Serum haptoglobin concentration measured upon arrival.

[5]Dry matter intake, expressed as a percentage of average BW for the period.

Table 3.8. Morbidity, mortality, and days on feed, severity score, and rectal temperature at the time of treatment for steers allotted to pens according to arrival serum haptoglobin concentration in Exp. 2.

	Arrival Haptoglobin Group[1]				
Item	ND	PRES	SEM[2]	Prob.[3]	Odds Ratio[4]
Morbidity, %[5]					
Total	37.72	57.30	3.75	0.17	2.21
Retreats	36.51	49.02	6.07	0.36	1.67
Third Pulls	5.43	13.56	3.07	0.03	2.73
T1	23.95	29.21	3.41	0.47	1.31
T2	8.38	12.36	2.47	0.44	1.54
T3	8.38	12.36	2.47	0.44	1.54
Chronic[6]	0.00	2.25			
Mortality, %[7]					
Total	0.60	2.81			
BRD	0.00	2.25			
First Treatment[8]					
Day	8.5	5.4	1.09	0.008	
Severity	1.3	1.5	0.16	0.03	
Temperature	40.95	40.96	0.101	0.92	
Second Treatment[8]					
Day	16.4	13.5	1.25	0.13	
Severity	1.6	1.8	0.17	0.31	
Temperature	40.70	41.02	0.103	0.05	
Third Treatment[8]					
Day	25.9	19.2	2.54	0.08	
Severity	1.3	2.1	0.23	0.03	
Temperature	41.19	40.61	0.185	0.04	

[1]Steers grouped based on serum Hp concentration measured on d 0. ND, not detectable; PRES, measurable concentration.

[2]Standard error of the least squares means (n = 6 pens/group). The greatest SEM is shown.

[3]Observed significance of the difference between treatment means.

[4]Odds ratio of PRES:ND.

[5]Total = percentage of steers treated at least one or more times for BRD; Retreats = numbers of steers requiring 2 or more BRD treatments, as a percent of those that required one treatment; Third pulls = percent of steers that required three treatments for BRD; T1, T2, T3 = the percent of steers that required 1, 2, or 3 total treatmenst (excluding those defined as chronically ill);

[6]Chronic = percent steers defined as chronically ill according to protocol. Due to the infrequent occurrence, data were not analyzed statistically.

[7]Mortality: Total, percent of animals that died during the study; BRD, percent of mortalities attributed to BRD. Due to the infrequent occurrence, data were not analyzed statistically.

[8]Day on trial; Severity score (1 = mild, 2 = moderate, 3 = severe, 4 = moribund); Rectal temperature, °C at the time of the first, second, or third treatment for BRD.

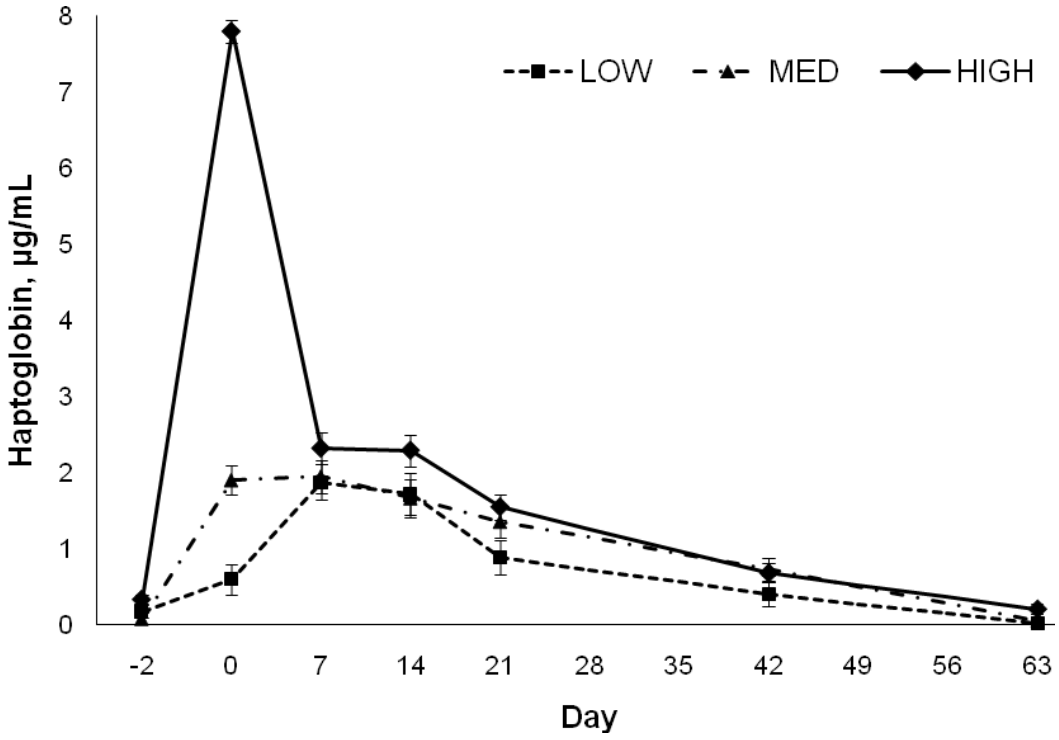

Figure 3.1. Serum haptoglobin concentrations (µg/ mL) of heifers in Exp. 1 grouped according to arrival Hp concentration (LOW, ≤ 1.0 µg/mL; MED, 1.0 to 3.0 µg/ mL; HIGH > 3.0 µg/mL) and measured over a 63-d receiving period. Haptoglobin group × Time interaction ($P < 0.001$; SEM = 0.274); Haptoglobin group ($P < 0.001$; SEM = 0.881); Day ($P < 0.001$; SEM = 0.143).

CHAPTER IV

EFFECT OF CLINICAL BOVINE RESPIRATORY DISEASE DURING THE GROWING PHASE ON SUBSEQUENT FEEDLOT GROWTH PERFROMANCE, CARCASS CHARACTERISTICS, AND BEEF ATTRIBUTES

ABSTRACT: Heifers with expected high risk of bovine respiratory disease (BRD; n= 360; initial BW = 241.3 ± 16.6 kg) were assembled at a Kentucky order buyer facility and delivered to Stillwater, OK in September 2007 to determine the effects of clinical BRD observed during preconditioning on subsequent feedlot performance, carcass characteristics, and meat quality. During a 63-d preconditioning period, morbidity and mortality attributed to BRD were 57.6% and 8.6%, respectively. Immediately following preconditioning, heifers were grouped according to health outcome category and allotted to finishing pens (5 to 7 heifers/pen). Heifers were never treated for BRD (0X; n = 9 pens), treated one time (1X; n = 9 pens), two times (2X; n = 6 pens), 3 times (3X; n = 6 pens), or designated as chronically ill (C; n = 2 pens). Arrival BW was not different (P = 0.21) among treatment categories. However, disease incidence during preconditioning decreased growth ($P < 0.001$), resulting in BW of 318, 305, 294, 273, and 242 kg for 0X, 1X, 2X, 3X, and C, respectively, at the start of the finishing phase. Estimates on the LM, taken by ultrasound on d 65 and 122, were combined with BW and visual appraisal to target common average end point within category and block. On average, heifers were slaughtered on d 163 for 0X, 1X, and 2X, d 182 for 3X, and d 189 for C ($P < 0.01$). Final

BW was similar for heifers treated 0, 1, 2, or 3 times ($P \geq 0.18$), but heifers deemed chronically ill weighed less ($P = 0.01$) than 3X. Considering the finishing phase only, ADG was linearly increased ($P < 0.001$) with increasing BRD treatments, but was linearly decreased ($P = 0.003$) as BRD treatments increased from arrival to slaughter. Therefore, G:F was greater ($P = 0.007$) for C than 3X and linearly decreased ($P = 0.002$) from 3X to 0X. Similar to BW, HCW was lower ($P = 0.03$) for C than 3X. Marbling score tended ($P = 0.06$) to decrease linearly as the number of treatments increased, but no other differences ($P \geq 0.24$) in carcass traits were detected. No differences were observed in beef tenderness ($P = 0.65$), and no consistent trends were noted in retail display or palatability data. Less than 20 additional days on feed were required for heifers treated 3 times to have similar weights and carcass characteristics to heifers never treated for BRD. Segregating and 're-starting' animals with multiple BRD treatments may be a viable alternative to realizing these cattle.

Key words: bovine respiratory disease, carcass, cattle, feedlot, growth

INTRODUCTION

Bovine Respiratory Disease (**BRD**) is the most important disease of feedlot cattle, (Edwards, 1996; Smith, 1998) causing 75% of morbidity and 50% of mortality. Costs associated with treatment, mortality, and decreased feed efficiency have been reported to cost the industry up to $750 million annually (Chirase and Greene, 2001). In addition, despite improved vaccines and antibiotics, BRD rates have been increasing (Loneragan et al., 2001; Babcock et al., 2006) during recent years. Feedlot cattle that received one, two, or three treatments for BRD returned a net of $40.64, 58.35, and $291.93 less, respectively, than untreated animals (Fulton et al., 2002). A substantial portion (79%) of the lost return was due to decreased carcass weight and lower quality grade rather than treatment costs (Gardner et al., 1999).

In multiple studies (Gardner et al., 1999; Roeber et al., 2001; Thompson et al., 2006; Schneider et al., 2009), treatment records and lung lesions have been used to quantify the effect of BRD on feedlot performance and carcass characteristics. A 4% decrease in average daily gain (**ADG**), 1.7% decrease in final body weight (**BW**), and a 2.6% decrease in hot carcass weight (**HCW**) were observed in steers treated for BRD (Gardner et al., 1999). However, inconsistencies exist within these data. Average daily gain observed by morbid animals has been reported as similar to, increased, or decreased when comparing healthy and treated animals (Roeber et al., 2001; Thompson, 2006), and Waggoner et al. (2007) observed no differences in carcass characteristics between treated and non-treated cattle. These reports also differ in the rate and severity of BRD reported and the method of selecting slaughter end point: 1) constant days on feed (Gardner et al., 1999); or 2) multiple, subjectively determined, slaughter groups (Waggoner et al., 2007;

Schneider et al., 2009). Furthermore, morbid and healthy animals were commingled throughout these experiments and measures of dry matter intake (**DMI)** and efficiency were not possible. The majority of BRD treatments occur early in the feeding period (Fulton, 2003; Babcock et al., 2007). Therefore, the objectives of this study were to observe newly received heifer calves with a high risk of developing BRD, commingled after arrival and during a 63-d growing period, segregate them into pens by BRD outcome group (never treated vs. number of times treated), slaughter animals from each outcome group based on a common end point, and observe feedlot growth performance and carcass traits. An additional objective was to determine the effect of BRD on meat shelf-life, tenderness, and palatability.

MATERIALS AND METHODS

Cattle and Growing Phase

Three hundred sixty British and British × Continental heifers (BW = 241.3 ± 16.6 kg) were assembled by Eastern Livestock at the West Kentucky Livestock Market (Marion, KY). As each truckload of 90 heifers was assembled, heifers were identified with an individually numbered dangle tag, administered an electronic ruminal temperature monitoring bolus (SmartStock LLC, Pawnee, OK) and had a blood sample collected via jugular venipuncture for serum harvest (Clott activator, Becton Dickinson Vacutainer Systems, Franklin Lakes, NJ). Heifers were then shipped 957 km to the Willard Sparks Beef Research Center (**WSBRC**), Stillwater, OK, in separate lots of 180 heifers each on September 11 and 13, 2007, respectively.

Heifers were allowed to rest for 5 to 6 h after arrival without access to feed or water prior to initial processing. This consisted of individually weighing, collection of an ear notch for the detection of animals persistently infected with bovine viral diarrhea virus (**PI-BVDV**; Oklahoma Animal Disease Diagnostic Lab, Stillwater, OK), and collection of a blood sample via jugular venipunture for serum harvest (Clott activator, Dection Dickinson Vacutainer Systems). After collection, blood samples were transported to the laboratory where they were allowed to clot at room temperature for 3 h. After clotting, blood samples were centrifuged at 3,000 × *g* at 4°C for 20 min. Serum haptoglobin (**Hp**) concentration was measured using a bovine ELISA test (Immunology Consultants Lab, Portland, OR). Samples were diluted 1:10,000 in tris buffered saline with tween 20, pH 4.0 (Sigma, St. Louis, MO) prior to analysis. The intra and inter assay coefficients of variation were below 5%. Heifers were categorized into BRD risk groups based on arrival serum Hp concentrations and allocated within arrival lot into receiving pens. Groups were **LOW** (< 1.0 µg/mL); **MED** (1.0 to 3.0 µg/mL); and **HIGH** (> 3.0 µg/mL) arrival Hp concentration.

The following morning, heifers were processed and sorted into their assigned pens. Processing consisted of vaccination against infectious bovine rhinotracheitis (**IBR**), bovine virus diarrhea (**BVDV**; Types I and II), bovine parainfluenza-3 (**PI3**), and bovine respiratory syncytial virus (**BRSV**; Pyramid 5, Fort Dodge Animal Health, Overland Park, KS) and clostridial pathogens (Vision 7, Intervet/Schering-Plough Animal Health, DeSoto, KS), deworming with moxidectin (Cydectin, Fort Dodge Animal Health), and implanting with estradiol and trenbalone acetate (Component TE-G, Vetlife, Overland Park, KS). Three hundred thirty-seven heifers (BW = 241 ± 16.6 kg) were used in the

experiment. Exclusion criteria included being PI-BVDV (n =1), misidentification of initial blood samples, and laboratory errors that required re-runs which could not be performed within the 24 h between arrival and processing (n = 22). Heifers were fed in 6 pens (12.2 × 30.5 m with a 12.2 m fence-line concrete feed bunk and fence-line water basin) per arrival lot with an average of 28 animals (range = 18 to 34) per pen. Care was taken so that LOW and HIGH Hp pens did not share a water basin. Heifers were fed twice daily, at 0700 and 1330 h, a 65% concentrate receiving/growing ration formulated to meet or exceed NRC (2000) nutrient requirements (Table 4.1). Each morning prior to feeding, bunks were visually evaluated for the presence of orts and feed calls were adjusted so that less than 0.22 kg/heifer remained each morning. However, calves were challenged on intake every 2 to 4 d throughout the experiment. On d 7, calves were individually weighed and revaccinated (Pyramid 5, Fort Dodge Animal Health). In addition to arrival and d 7, individual weights were captured on d 14, 21, 42, and 63.

Assessment and Treatment for Signs of BRD

Each morning trained individuals evaluated animals for signs of BRD. Evaluation was performed according to standard protocol for the facility based on the DART system (Pharmacia Upjohn Animal Health, Kalamazoo, MI) with some modifications as described by Step et al. (2008). Subjective signs included evidence of depression (hanging head, sunken or glazed eyes, slow movement, arched back, difficulty in rising, knuckling or dragging toes when walking, and stumbling); abnormal appetite (completely off feed, eating less than or with less aggression than penmates, lack of fill, or obvious BW loss); and respiratory signs (obvious labored breathing, extended head and neck, and

noise when breathing). Based on the presence of one or more of these signs, and the severity of the sign(s), the evaluators assigned a severity score from 1 to 4, where 1was mild, 2 was moderate, 3 was severe, and 4 was moribund. All calves assigned a severity score were removed to the processing chute for rectal temperature measurement (GLA M-500; GLA Agricultural Electonics, San Luis Obispo, CA). For animals assigned a severity score of 1 or 2, antimicrobial therapy was administered according to protocol if rectal temperature was ≥ 40.0°C. However, animals assigned severity scores of 3 or 4 were administered antimicrobial therapy regardless of rectal temperature. A maximum of three antimicrobial therapies (treatments) were allowed during the experiment, and all doses were calculated by rounding the current BW up to the nearest 11.3 kg. Antimicrobials were administered following Beef Quality Assurance Guidelines (NCBA, 2001) via a subcutaneous injection. The first treatment was administered in the left neck, and subsequent injections were given in alternating sides of the neck. When treatment criteria were met the first time, 10 mg tilmicosin/kg BW (Micotil 300, Elanco Animal Health, Greenfield, IN) were administered. For the second treatment, a moratorium of 120 h was followed before a second administration could be given. This time period was shortened to 72 h when a severity score of 3 or 4 was assigned. When criteria were met for a second treatment, 10 mg enrofloxacin/kg BW were administered (Baytril 100, Bayer Animal Health, Shawnee Mission, KS). Following a 48-h period, heifers meeting treatment criteria were eligible to receive ceftiofur hydrochloride (Excenel RTU, Pfizer Animal Health, New York, NY). Excenel therapy consisted of 2 doses (2.2 mg/kg BW) given 48-h apart. When subjective and temperature criteria were not met, no

antimicrobial was given, and both treated and not-treated animals were returned to their home pens following evaluation.

Beginning on d 21 and each day after, standards for defining chronically ill animals were instituted, and those animals identified as chronically ill were removed from their home pens. In order to be defined as chronically ill, an animal must have previously been administered all three antimicrobial therapies according to protocol and at least 48 h had passed after the last dose of Excenel was given. The animal must have been on trial longer than 21 d and have a net loss of weight over the most recent 21-d period. Additionally, the heifer must have been assigned a severity score of 3 or 4 on the day she was removed from the experiment.

Finishing Phase

Following the 63-d growing phase, 193 heifers were selected to begin the finishing phase of the experiment. All calves were classified according to the number of antimicrobial treatments for BRD they had received during the growing phase and assigned to the following outcome groups (Table 4.2): never treated (**0X**), treated 1 time (**1X**), treated 2 times (**2X**), treated 3 times (**3X**), and heifers identified as chronically ill (**C**). Heifers were automatically excluded from the finishing phase if they were visually lame (n = 1) or treatment protocol was not followed during the growing phase (n = 5). All heifers that qualified in the 2X (n = 34), 3X (n = 39), and C (n = 12) groups were used in the finishing phase. For the 0X and 1X groups, heifers were stratified within group by d 63 BW and 54 heifers from each group were randomly selected for the finishing period using a random number generator maintaining a similar BW distribution

between the total number and the sample selected. Within all outcome groups, heifers were then blocked by weight and randomly assigned to feedlot pens. Nine pens each were used for 0X and 1X (n = 6 heifers/pen), 6 pens each were used for 2X and 3X (n = 5, 6, or 7 heifers /pen), and 2 pens were used for C (n = 6 heifers/pen). Pens were 4.57 × 15.24 m with a 4.57 m fence-line feed bunk and 4.57 m deep concrete apron extending into the pen. Feed bunks and aprons were covered with a metal awning. Adjacent pens shared a fence-line automatic water basin. Heifers had 9.9 to 13.9 m^2 of pen space and 65 to 91 cm of bunk space available per animal. Three or 5 days following the final BW from the growing experiment (d 0) heifers were individually weighed, implanted with estradiol and trenbalone acetate (Revalor-IH, Intervet/Schering-Plough Animal Health, Millsboro, DE), and sorted into their final pens. Over the next 19 d, a series of 3 diets with increasing concentrate density was fed until the heifers were adapted to the final finishing diet (Table 4.1). Similar to the growing phase, cattle were fed twice daily beginning at 0700 and 1330, respectively, and bunks were managed such that no orts or less than 0.22 kg/animal remained prior to feeding each morning.

Body weights were recorded on d 28, 65, 100, 122, 152, 174, and 189. On d 65 and 122, all animals had *Longissimus* muscle (**LM**) and 12th-rib fat characteristics estimated by ultrasonography (C. Gordon, Ultrasound Technologies, Fletcher, OK). Estimated characteristics included LM area, fat thickness (**FT**), and percent intramuscular fat (**IMF**). Based on these estimates, BW gain, and visual appraisal, heifers were targeted for slaughter at equal compositional endpoints based on fat thickness (1.27 cm) and estimated percent body fat (28%). Slaughter dates were common for all animals in the same BRD outcome group within weight block. Final BW were obtained before feeding

1 d prior to slaughter, after which animals were returned to their home pens and fed 75% of the previous day's allotment of feed. Trucks were loaded at approximately 1700 h and heifers were hauled 478 km to a commercial abattoir for slaughter the following morning.

Lung Lesion Assessment

The presence and severity of lesions on the lungs as evidence of prior bronchopneumonia of heifers were determined using a scoring procedure based on that of Bryant et al. (1999). Lungs were scored in the plant at chain speed using visual appraisal and brief palpation. For each side (right and left) the presence and severity (0, 1, 2, 3) of lesions were recorded, along with the absence or presence (0, 1) of interlobular adhesions or missing lobes indicating thoracic adhesions. Overall evidence of bronchopneumonia (0, 1) was based on the presence of a lesion, adhesion, or missing lobe for each side and the overall lung.

Carcass Characteristics and Meat Quality Sample Collection.

Trained personnel from Oklahoma State University collected carcass data which included HCW, LM area, marbling score, estimated percent internal fat (**KPH**), and 12th-rib fat thickness. Yield grade was calculated from HCW, LM area, 12th-rib fat, and KPH, and quality grade was determined from marbling score and maturity data. The frequency (0, 1) of condemned livers was also observed. Following a 36-h chill, carcasses were fabricated according to Institutional Meat Purchasing Specifications (**IMPS**; USDA, 1996). A strip loin was fabricated from each carcass, vacuum packaged, and transported to the Robert M. Kerr Food and Agricultural Products Center, Stillwater, OK (**FAPC**) for

further analysis. Strips were aged for 14 d in the vacuum package bag at 3 ± 1°C. After aging, one steak (2.54 cm) from each carcass was cut, placed on a styrofoam retail tray, and overwrapped with polyvinyl chloride film for retail display analysis, and two steaks (2.54 cm) were cut, vacuum packaged, and frozen in a blast freezer (-20° to -40°C); frozen samples were held in a freezer (-10°C) until further analysis.

Retail Display and Color Analysis

An open topped, coffin-chest display case (M1-8EB, Hussman, Bridgeton, MO) maintained between 2 and 4°C was used to simulate retail display of packaged steaks. Steaks were packaged on a styrofoam tray with soaker pad and over-wrapped with polyvinyl chloride film. Packages were displayed under continuous, 1,600 lux of cool-white fluorescent lighting (Bulb No. F40 T12, Promolux, BC, Canada). Beginning at 0 h under display conditions and every 12 h for 108 h, each package was subjectively evaluated by a trained panel. Packages were rotated daily, such that they were exposed to all conditions of light angles and intensities and environmental effects associated with defrost cycle and location within the case. Muscle color, surface color, and overall appearance were evaluated (AMSA, 1991). Muscle color was characterized on an 8-point scale (1 = extremely dark red, 2 = dark red, 3 = moderately dark red, 4 = slightly dark red, 5 = slightly bright cherry red, 6 = moderately bright cherry red, 7 = bright cherry red, and 8 = extremely bright cherry red). Scores for surface discoloration were assigned based on a 7-point scale [1 = no (0%) discoloration, 2 = slight (1 to 19%) discoloration, 3 = small (20 to 39%) discoloration, 4 = modest (40 to 59%) discoloration, 5 = moderate (60 to 79%) discoloration, 6 = extensive (80 to 99%), and 7 = total (100%)

discoloration]. Overall appearance was scored on an 8-point scale (1 = extremely undesirable, 2 = very undesirable, 3 = moderately undesirable, 4 = slightly undesirable, 5 = slightly desirable, 6 = moderately desirable, 7 = very desirable, and 8 = extremely desirable). Similarly, steaks were objectively evaluated for instrument color beginning at 0 h under display conditions and every 12 h thereafter for 108 h. The color of each steak was measured using a HunterLab Miniscan XE Plus Spectrophotometer (2.50-cm aperture, 10º standard observer, Illuminant D65, HunterLab Associates Inc., Reston, VA). Color coordinate values were determined according to the procedures of the Commission Internationale d'Eclairage (CIE, 1976) for L* (brightness, 0 = black and 100 = white), a* (redness/greenness, positive values = red and negative values = green), and b* (yellowness/blueness, positive values = yellow and negative values = blue). Three independent readings for each of the L*, a*, and b* values were taken at different locations on the meat surface and averaged for each steak.

Sensory Analysis

For sensory analysis, steaks were allowed to thaw at 4°C for 24 h prior to cooking and broiled at 200°C on an impingement oven (ZLT Impinger, Model 3240-TS, BOFI Inc., Wichita, KS). After reaching an internal temperature of 68°C (Atkins AccuTuff 340, Atkins Temtec, Gainesville, FL) steaks were sliced into 2.54 cm × 1.27 cm × 1.27 cm samples. Panelists (n = 7) that had previously been trained according to AMSA guidelines (1995) evaluated warm samples for initial and sustained juiciness, initial and overall tenderness, and amount of connective tissue using an 8-point scale. Panelists evaluated cooked beef flavor, painty/fishy, and livery/metallic off-flavor intensity using a

3-point scale. For juiciness, the scale was 1 = extremely dry, 2 = very dry, 3 = moderately dry, 4 = slightly dry, 5 = slightly juicy, 6 = moderately juicy, 7 = very juicy, and 8 = extremely juicy. The scale used for initial and overall tenderness was 1 = extremely tough, 2 = very tough, 3 = moderately tough, 4 = slightly tough, 5 = slightly tender, 6 = moderately tender, 7 = very tender, and 8 = extremely tender. The scale used for connective tissue was 1 = abundant, 2 = moderately abundant, 3 = slightly abundant, 4 = moderate, 5 = slight, 6 = traces, 7 = practically none, and 8 = none. The scale used for beef flavor and off-flavor intensity was 1 = not detectable, 2 = slightly detectable, and 3 = strong.

Warner-Bratzler Shear Force

Prior to Warner Bratzler shear force (**WBSF**) determination, steaks were thawed and cooked as described above. After cooking, steaks were cooled at 4°C for 18 to 24 h. Six cores, 1.27 cm in diameter, were removed parallel to muscle fiber orientation and sheared once using a Warner-Bratzler head attached to an Instron Universal Testing Machine (Model 4502, Instron Corporation, Canton, MS). The Warner-Bratzler head moved at a crosshead speed of 200 mm/min. Peak load (kg) of each core was recorded by an IBM PS2 (Model 55 SX) using software provided by the Instron Corporation. Mean peak load (kg) was analyzed for each of the six cores and was then averaged over the sample to determine the WBSF for the sample.

Statistical Analysis

Animal growth performance and carcass characteristics were analyzed as a randomized complete block design considering pen as the experimental unit. There were two blocks for each of the 5 BRD outcome categories. The MIXED procedure of SAS (SAS 9.1, SAS Institute, Cary, NC) was used to analyze continuous growth, carcass, and meat quality variables. For animal performance variables, the model statement included BRD outcome group as a fixed effect and the random statement included weight block. Non-parametric data (proportion of carcasses in quality and yield grades and proportion of lungs with lesions present) were analyzed as binomially distributed using the logit link with the GLIMMIX procedure of SAS using the mixed model listed above. Least squares means were calculated using SAS and the ilink option was used to obtain frequency estimates and standard errors. Because this approach views the multinomial distribution of USDA quality grades, for example, as a series of binomial proportions, inference should not be made between categories of a particular variable.

Meat quality data was analyzed as a completely randomized block design with the MIXED procedure of SAS. Individual animal was considered the experimental unit. The model statement contained the fixed effect of BRD outcome category and the random statement included harvest group (1, 2, or 3). Repeated measures analysis was used to analyze both objective and subjective measures of retail display characteristics. The model was subjected to multiple covariance structures and the best fit model was selected to contain the covariance structure that yielded the smaller Akaike and Schwarz's Bayesian criterion based on their – 2 res log-likelihood. With the exception of L*, which was analyzed using a heterogeneous Toeplitz covariance structure, all other variables of

objective and subjective retail display were analyzed using a first order ante-dependence covariance structure.

For all analyses, contrasts were used to test the linear and quadratic responses of increasing the number of treatments for BRD from 0 to 3. Polynomial contrast coefficients were weighted to compensate for unequal sample sizes. In addition, the response of receiving 3 treatments for BRD was contrasted against that of heifers deemed chronically ill. In order to control Type I error rate when using contrasts which are not mutually orthogonal, differences or tendencies are only discussed when the probability associated with the F statistic is ≤ 0.05 or ≤ 0.10, respectively.

RESULTS

Morbidity attributed to signs of BRD was 57.6%, and total mortality was 8.6%. The case fatality rate was 13.1%. The breakdown of heifers into their BRD outcome groups was 113 (33.53%) 0X; 100 (29.67%) 1X; 34 (10.09%) 2X; 39 (11.57%) 3X; and 13 (3.86%) C (Table 4.2). Therefore, based on the selection criteria described above 54, 54, 34, 39, and 12 heifers were enrolled in 0X, 1X, 2X, 3X, and C pens, respectively. Descriptive statistics including mean days on feed for each treatment, removal, or mortality, severity score, serum Hp concentration, and rectal temperature at time of treatment are shown in Table 4.2. During the finishing period, two heifers were treated for signs of BRD with 6 mg/kg danofloxacin mesylate (A180, Pfizer Animal Health). One heifer from the 2X treatment was treated on d 149 and remained in her home pen for the duration of the trial. One heifer from the C treatment was removed from her home pen on d 94 due to the severity of clinical signs and treated and died on d 97. Three

additional heifers died from digestive causes during the finishing phase (1 heifer each from 0X, 3X, and C treatments).

Body weight upon arrival at the facility was not different ($P = 0.21$) between heifers that had differing numbers of subsequent treatments for BRD (Table 4.3). However, after the 63-d growing period, there was a linear decrease ($P < 0.001$) in BW as the number of treatments for BRD increased from 0 to 3. The range in mean BW for those categories was 45 kg. Furthermore, there was 30 kg lower ($P < 0.001$) BW of heifers that were deemed chronically ill compared to those treated three times. Similar linear decreases ($P < 0.001$) in BW were observed through d 122 during finishing, but by that time the difference between heifers never treated for BRD and those treated 3 times was 28 kg. However, the difference in BW between heifers treated 3 times and heifers deemed chronically ill remained large (26 kg) after 122 DOF. When averaged across days on feed, no trend ($P \geq 0.18$) could be determined to separate final BW of heifers, regardless of BRD treatment category. However, chronics were 19 kg lighter ($P = 0.01$) than 3X immediately prior to slaughter. Average daily gain was not different ($P \geq 0.19$) among heifers treated different times for BRD from days 0 to 28, 29 to 65, 66 to 122, 123 to end, or 0 to end. Chronic heifers gained less ($P < 0.006$) than those treated three times during days 0 to 28 and 0 to 65, but overall finishing period ADG was similar ($P = 0.38$) between 3X and C. When the preconditioning period was included and ADG calculated, there was a linear decline ($P = 0.003$) in ADG as the number of treatments for BRD increased. Overall (arrival to end) ADG was 1.29, 1.26, 1.26, and 1.18 kg/d for 0X, 1X, 2X, and 3X, respectively. In addition, the overall ADG of C heifers (1.06 kg/d) was less ($P = 0.03$) than those requiring three BRD treatments.

During days 0 to 28 of finish, there were linear and quadratic decreases ($P < 0.001$) in DMI as the number of treatments for BRD increased from 0 to 3, and C was less than 3X ($P = 0.02$). A similar linear decrease ($P < 0.001$) in DMI with increasing BRD treatments was noted from days 0 to 65, but overall DMI was not different ($P \geq 0.13$) due to the number of BRD treatments. Dry matter intake remained less ($P \leq 0.02$) for C than 3X during days 29 to 65. However, no differences ($P = 0.47$) in DMI were noted later in the feeding period regardless of BRD treatment category or chronic status. When DMI was expressed as a percent of mean BW (**PDMI**), there was a quadratic effect ($P = 0.01$) from d 0 to 28 in which 2X steers consumed more than 0X, 1X, or 3X. Later in the feeding period (d 123 to end), there were linear increases ($P = 0.03$) in PDMI as number of BRD treatments increased from 0 to 3. However, overall PDMI was similar ($P \geq 0.61$) among BRD treatments from d 0 to end. Heifers treated three times had similar ($P \geq 0.11$) PDMI across the entire finishing period. Due to the similar ADG and decreased DMI observed between BRD treatment categories, the ratio of ADG to DMI (**G:F**) was increased (linear, $P = 0.002$) as number of treatments increased during days 0 to 65. This increase in G:F tended ($P = 0.07$) to continue from d 66 to 122 as well. Heifers identified as chronically ill were more ($P = 0.01$) efficient than 3X during days 0 to 28 and 66 to 122 ($P = 0.005$). Overall G:F was increased (linear, $P = 0.002$) from 0.142 to 0.168 as the number of BRD treatments increased from 0 to 3. Day 0 to end G:F for C heifers was 0.186 (3 vs. C, $P = 0.04$).

Loin muscle area estimated by ultrasonography linearly decreased ($P = 0.01$) as the number of BRD treatments increased from 0 to 3 on d 65, but was not different ($P \geq 0.31$) on d 122 (Table 4.4). However, C heifers had smaller estimated LM area ($P \leq$

0.02) than 3X, both on d 65 and 122. The difference was 15.2 cm^2 on d 65, but only 9.3 cm^2 on d 122. On both d 65 and 122, the percent IMF estimates tended to be linearly decreased ($P \leq 0.09$) as the number of treatments for BRD were increased, but no differences ($P \geq 0.20$) in percent IMF were detected between 3X and C heifers at either ultrasound measurement. Similarly, estimated 12^{th}-rib FT was decreased linearly ($P \leq 0.001$) as the number of BRD treatments increased, and C heifers had approximately 0.2 cm less FT ($P \leq 0.02$) both on d 65 and 122.

At the time slaughter when carcass characteristics were measured, similar to final BW, HCW was not different ($P = 0.21$) among BRD treatment categories, but was decreased ($P = 0.007$) in C compared to 3X heifers (Table 4.4). No difference ($P \geq 0.11$) in dressing percent, which ranged from 61.7 (C) to 63.7 (1X), was detected. No other differences ($P \geq 0.12$) in carcass characteristics were observed due to number of treatments for BRD or chronic status. Similarly, the distribution of heifers in USDA Quality and Yield Grades was not different ($P \geq 0.42$; Table 4.5).

Overall evidence of previous pneumonia observed in the lungs at slaughter was not different ($P = 0.59$; Table 4.6) among BRD treatment categories. Similarly, there were no differences ($P \geq 0.25$) in the frequencies of severe lung lesions, interlobular adhesions, missing lobes, nor any pulmonary lesion attributes were observed in the left or right lungs individually corresponding to the number of BRD treatments.

Retail display characteristics of strip loin steaks are shown in Table 4.7. There were BRD treatment category × time interactions ($P < 0.001$) for muscle color and overall appearance of retail display characteristics of steaks (data not shown). As expected, muscle color decreased, surface discoloration increased, and desirability overall

appearance diminished over time ($P < 0.001$; data not shown). However, no pattern in the decline of color or overall appearance due to BRD treatment category was apparent. As the number of BRD treatments increased, a linear decrease ($P = 0.01$) in muscle color was observed. A quadratic increase in surface discoloration tended ($P < 0.10$) to occur in steaks from 2X heifers. Significant BRD treatment category × time interactions were observed for L*, a*, and b* measures of color ($P < 0.001$; data not shown). No differences in WBSF were observed due to BRD treatment history ($P = 0.65$; Table 4.8). Steaks from C carcasses had lower ($P \leq 0.06$) initial juiciness than steaks from 3X carcasses. However, no other differences ($P \geq 0.15$) in palatability measures were observed.

DISCUSSION

The overall morbidity attributed to clinical signs of BRD in the present experiment was 57.6%. In recent published experiments conducted at the WSBRC, observed total morbidity rates in newly received, auction-market sourced calves ranged from approximately 2.5% (Group 1; Step et al., 2007) to 64.0% (Berry et al., 2004). Edwards (1996) reported that BRD contributed to 75% of the morbidity in feedlots and that total morbidity from all causes was consistently around 8% of feedlot cattle received. Loneragan et al. (2001) reported 1.2% mortality, of which 57.1% was attributed to respiratory disease, in cattle received into the USDA-NAHMS sentinel feedlot monitoring program between 1994 and 1999. Our calves were most likely recently weaned before transport to the original auction market, commingled at the auction market and order buyer receiving facilities, shipped nearly 1,000 km, and appeared stressed upon

arrival at our facility. This would classify them as high risk (Edwards, 1996). The higher morbidity and mortality of cattle in the present experiment compared to the averages reported by surveys results due to surveys including all cattle received into feedlots – both high risk and low risk. Nevertheless, commercial operations have reported high morbidities (80%; Sanderson et al., 2008) in individual pens of cattle. Low-risk cattle would include weaned or backgrounded cattle and yearling animals from a single source. These calves typically have lower BRD incidence rates and morbidity (Step et al., 2008). Low-risk yearling cattle would contribute a large number to the populations reported by Edwards (1996) and Loneragan et al. (2001). One advantage to the high morbidity and numbers of animals requiring multiple treatments observed in the present experiment is the ability for replicating these outcome categories for the finishing phase of the experiment.

We chose a growing period of 63 d prior to classifying our heifers according to BRD outcome group. Reasons for this decision were two-fold and related to arrival BW and the high likelihood that the majority of BRD treatments, including multiple treatments when necessary, would occur within the 63-d window. The average arrival BW of 241 kg would be common for fall weaned calves in the United States. Expecting an approximate 1 kg of ADG during the growing period, heifers would then have appropriate BW to expect a 150 to 175-d finishing period, typical of commercial feedlots. Experience in our facility suggests that both initial and subsequent treatments for signs of BRD would virtually cease by the end of the 63-d growing phase. This is also supported by the literature. For example, Thompson et al. (2006) observed that 87% of all BRD treatments had occurred by 35 days after arrival, and 74% of morbidity during a 5-year

survey of a commercial feedlots occurred within the first 42 days on feed (Babcock et al., 2009). The mean days after arrival to first treatment in that study were 30, but new cases peaked within 14 d of arrival (Babcock et al., 2009). In the present experiment, the mean days after arrival to first treatment were less than approximately 1 week for each of the BRD outcome groups, and 46% required more than one antimicrobial treatment. Babcock et al. (2009) also noted, in cattle of similar BW, an increased risk of multiple treatments associated with earlier initial treatment.

Similar to the present experiment, arrival BW has often not differed between cattle that were never treated and those that required antimicrobial treatment for signs of BRD (Gardner et al., 1999; Waggoner et al., 2007). Similarly, initial BW has been reported to have no effect on the success of BRD antimicrobial treatment or relapse rate (Bateman et al., 1990). However, a linear decrease in arrival BW has also been reported for heifers treated 0 to 3 times (Montgomery et al., 2009). In addition, the linear decrease in BW associated with increasing treatments for BRD after the 63-d growing period is supported by previous data (Gardner et al., 1999; Thompson et al., 2006; Schneider et al., 2009). A difference between the present experiment and that of Gardner et al. (1999) is that the cattle in their study were all slaughtered on d 150 or 151, and this date was presumably determined based on the average visual composition of cattle in the study. The use of ultrasonography combined with animal performance and visual appraisal allowed us to slaughter heifers when each BRD outcome category was expected to have 1.27 cm of 12-th rib fat. Therefore, heifers in the 3X and C groups were fed an average 19 and 26 d longer, respectively, than 0X, 1X, and 2X heifers. Because of this, final BW in our experiment was not different between 0X and 3X. Roeber et al. (2001) and Waggoner et

al. (2007) evaluated animals enrolled in the Rocky Mountain (Roeber et al., 2001) and New Mexico (Waggoner et al., 2007) Ranch to Rail Programs where animals were slaughtered on a market-ready basis. Similarly, final BW was not different between animals administered differing numbers of BRD treatments. Waggoner et al. (2007) reported the mean days on feed of cattle that were never treated (193), treated one time (200), and treated 2 or more times (212). While we slaughtered all 0X, 1X, and 2X heifers at the same time, the 19 d difference between healthy calves and those treated 2 or more times in the study of Waggoner et al. (2007) is consistent with the present data.

Growing-phase and overall (arrival to end) ADG are consistent with other reports with heifers treated 3 times having 59 and 8.7% lower ADG than heifers who remained healthy throughout the feeding period, respectively. After the low growing phase gain by morbid animals, a compensatory response was noticed in those animals, such that overall finishing-phase ADG was similar across BRD treatment categories. This is similar to Thompson et al. (2006) who observed a 169 g decrease in ADG during the first 35 days on feed by morbid animals, but no difference in ADG from d 35 to slaughter. Decreased ADG by morbid animals during the receiving phase was followed by increased ADG on grass (Montgomery et al., 2009), and ultimately equivalent ADG in the feedlot (Montgomery et al., 2009; Schneider et al., 2009). Existing data investigating the effects of BRD on feedlot cattle performance is derived primarily from correlating cattle performance with treatment records in a commercial feedlot. The present experimental design allowed us to measure DMI of feedlot cattle that had required differing numbers of treatments for BRD. However, we were unable to quantify feed intake by BRD outcome category during the time when the animals were exhibiting clinical signs and

administered treatment. Hutcheson and Cole (1986) summarized 18 studies where they observed that only 83.4% of calves identified as morbid had eaten by d 7 after feedlot arrival, compared with 94.6% of healthy calves. Similarly, DMI of morbid calves was 58, 68, and 88% of healthy calves during the first week, 4 weeks, and 8 weeks, respectively. Using a radiofrequency monitoring system, Sowell et al. (1999) recorded the frequency and timing of visits made to the feed bunk by newly received calves during receiving and growing periods. In one experiment, 94% of calves identified as healthy and 87% of morbid calves visited the feedbunk on the day of arrival, but 100% of healthy calves and only 91% of morbid calves visited the bunk by day 3 (Trial 1; Sowell et al. 1999). However, in another trial, only 13 and 10%, respectively, visited the feedbunk on d 1 (Trial 2). Again, all healthy calves had visited the bunk by d 4, although only 76 of morbid calves were observed at the feedbunk. In both trials, healthy calves had more overall feeding bouts per day and spent more time at the bunk daily than did morbid animals, both over the first 4 days and throughout the 32-d trial. In Trial 1, 52% of calves were identified as morbid, and 82% were classified as morbid in Trial 2, but a similar 80% of morbid calves were identified within 10 d of arrival in both trials. Using similar technology, Buhman et al. (2000) noted no difference in the frequency or duration of visits to the feed bunk between healthy and morbid calves for days 1 to 3, 4 to 5, or 6 to 10 after arrival. From day 11 to 27, sick animals had approximately 3 fewer visits and spent nearly 20 fewer minutes at the bunk daily than healthy animals. However, from d 28 to 57 of the growing period, animals that had been identified as morbid visited the bunk nearly one additional time daily than did healthy animals. Notable were the days on

feed when BRD was identified. Of the 170 calves enrolled in two studies, 43 were treated; 27 by d 11, 12 between d 11 and 27, and 4 between d 28 and 56.

The linear decrease in growing phase ADG observed in the present experiment by calves that required more treatments for signs of BRD could be the result of less DMI by morbid calves. Burciaga-Robles (2009) observed decreased DMI after a combined BVDV and *Mannheimia haemolytica* challenge in beef steers. The largest discrepancy in DMI occurred immediately after the challenge, but challenged steers had inferior DMI throughout the 112-d finishing period. Using an experimental design similar to that of the present experiment, McBeth et al. (2001) segregated heifers by BRD treatments (0 or 1) administered during a 42-d preconditioning period. At the beginning of the finishing phase, no difference in BW between healthy and morbid steers was observed. However, ADG was increased 14.4 and 5.8% during days 0 to 28 and 0 to 112 for treated heifers compared to those that were not treated during preconditioning. While DMI was not different at any time during the 140 d finishing period, the increase in ADG made treated heifers more efficient during the first 28 days on feed. Morbid steers in the trial of Gardner et al. (1999), similar to most commercial feedlots, were maintained in a hospital pen for a minimum of 3 d each time they were removed for BRD treatment. The authors noted that while in hospital pens, the calves were fed diets containing more hay, and thus, less net energy. Therefore, decreased feed intake, decreased energy intake, or a combination of the two could explain the decreased ADG and BW of the morbid calves in their trial. In our experiment, after animals were removed to the chute for rectal temperature evaluation and antimicrobial treatment, they were returned to their home pen. Therefore, all calves received the same rations during the growing and finishing

phases, respectively, and differences in energy intake not resultant from differences in DMI or diet sorting were not the cause of decreased ADG observed by morbid animals in the growing phase. An exception were the heifers deemed chronically ill, who were removed according to the described protocol. They were fed the same growing ration along with additional grass hay to stimulate intake in pens designated for chronically ill animals after they were removed from their home pens. No other calves removed from the home pen for an extended period of time were enrolled in the finishing portion of the experiment.

Additional evidence for low DMI by morbid calves, and subsequent compensation, can be inferred from the study of Jim et al. (1993), who selected 256 healthy and 256 sick animals from 1,124 within 4 days after arrival at a research feedlot. For an animal to be classified as sick, rectal temperature was required to be elevated (≥40.5°C) both 48 and 72 h after processing. During the first 48 h after processing, sick animals lost 0.5 kg/d, while healthy calves gained 1.53 kg/d. All animals were commingled from processing on d -3 to d 0 when sick animals were determined and pens were allocated, so DMI could not be measured. However, the difference in ADG between sick and health animals is likely resultant from shrink occurring in the sick animals, who were likely not eating, or eating less than healthy calves (Hutchison and Cole, 1986). During the next 27 d, sick animals gained 11% more than healthy animals while eating 0.3 kg/d less DM (Jim et al., 1993). Overall, d 0 to slaughter, ADG and DMI were not different between sick and healthy calves, but the ratio of DMI:ADG was 3.15% lower for animals identified as sick upon arrival. However, when DMI and DMI:ADG were extrapolated from processing to d 0 no differences were determined. The compensatory response in early gain and

efficiency may have occurred because sick cattle regained lost gut fill after segregation. In their experiment an additional 6.6 and 4.7% morbidity was observed in sick and healthy calves after allocation. Therefore, the differences in finishing DMI and feed efficiency could be biased by the timing of subsequent morbidity.

The pen (9.9 to 13.9 m^2) and feedbunk (65 to 91 cm) space available to the heifers in the finishing phase of the current study were generous. Therefore, little competition at the feedbunk would be expected, and none was apparent. It is possible that when cattle are not visiting the feedbunk due to loss of appetite from an immune challenge, or vice-versa, in a commercial feedlot, regaining a suitable location on the hierarchical order might be difficult or lengthy. Similarly, if feedlot cattle are maintained in a series of hospital and recovery pens further ration adaptation may slow intake upon return to home pens. These possibilities could limit intake and performance by animals recovering after an immune challenge has been controlled.

One of the goals in the present experiment was to slaughter all animals at a similar target endpoint. Using a combination of animal performance, ultrasound estimates, and visual assessment, we were successful at meeting similar endpoint. Final BW and HCW were not different among animals who were treated from 0 to 3 times for signs of BRD. In addition, only 0.14 cm difference in 12th-rib fat thickness was observed between heifers across treatment categories. However, heifers that had been classified as chronically ill had lower final BW and HCW and numerically lower 12th-rib fat thickness. Due to the desired sample collection and the distance of the abattoir from the research feedlot, logistical concerns compelled us to slaughter both blocks of the C heifers earlier than preferred, on d 189. Given the average performance of the C pens

from d 152 to 189 (ADG = 1.15 kg/d; DMI = 8.97 kg/d; G:F = 0.129), it is reasonable to assume similar final BW and carcass characteristic endpoints would have been achievable for those animals in less than 30 more days on feed. Aside from the performance differences highlighted between 3X and C treatments, the lack of differences in all carcass traits relative to BRD treatment status indicates that given the time and necessary energy intake, surviving morbid animals may reach their potential to produce a similar product to animals that remain healthy throughout the entire feeding period. Gardner et al. (1999) and Roeber et al. (2001), similar to the present study, reported no differences in HCW between animals never treated and those treated only 1 time. However, cattle receiving more than 1 BRD treatment had a 5% (Gardner et al., 1999) and 3% (Roeber et al., 2001) decrease in HCW compared to those that received only 1 treatment. This difference corresponded to a 1 percentage unit drop in dressing percentage (Gardner et al., 1999). Generally, animals treated for BRD also had leaner carcasses than those that required no treatments (Gardner et al., 1999; Roeber et al. 2001). Decreases in 12th-rib fat thickness and estimates of decreased internal fat with increasing number of BRD treatments corresponded with an approximate 1.3% decrease in calculated yield grade as well. No differences in LM area were noted in those reports. However, marbling score was decreased as number of BRD treatments increased (Gardner et al., 1999; Roeber et al., 2001). This is similar to the present data, that while no differences in HCW, fat thickness, LM area, internal fat, or yield grade were observed, a linear trend ($P \leq 0.10$) of decreasing marbling score occurred as the number of BRD treatments increased. McNeill et al. (1996) reported only 27% of cattle who had been treated for BRD in feedlots graded U.S. Choice, and Schneider et al. (2009) reported 16%

fewer animals from BRD treatment groups graded U.S. Choice than did non-treated animals, similar to the present experiment. In addition, those that required multiple treatments (3) were 5 times more likely to grade U.S. Standard than non-treated cattle (McNeill et al., 1996).

No trend in the presence or severity of respiratory tract lesions between treated and non-treated animals was observed in this study. Similarly, in previous reports, the presence of lesions is inconsistent with treatment records (Wittum et al., 1996; Bryant et al., 1999; Buman et al., 2000; Gardner et al., 1999; Buhman et al., 2000; Thompson et al., 2006). In these reports, a portion of cattle that had never been treated for signs of BRD had lesions present on the lungs and a portion of animals that were treated had no evidence of prior lung damage. Within published reports, the proportions of affected lungs are 16.9% vs. 72% (Buhman et al., 2000), 42% vs. 42% (Bryant et al., 1999), 68% vs. 78% (Wittum et al., 1996), and 61% vs. 74% in the present experiment for non-treated vs. treated animals, respectively. When comparing the number of treatments for BRD, Reinhardt et al. (2009) observed that the percentages of cattle with lung lesions present at slaughter tended to increase as the number of BRD treatments increased from 0 to ≥ 2. In addition, lesions affected 38.5% of animals never treated, 55.4% of those treated 1 time, and 66.7% of those with 2 BRD treatments (Thompson et al., 2006). The inconsistencies with lung lesions and treatment records can be attributed to: 1) differences in pathogens; 2) differences in animal type and management between trials; 3) the lesions observed may be a remnant of infection that occurred prior to the period when clinical health was observed; 4) due to antimicrobial treatment or the animal's immune system, full recovery of the infection occurred and the lesion was resolved; or 5) the lesions observed were

resultant from a subclinical infection. Although Wittum et al. (1996) and Bryant et al. (1999) indicated that the presence of pulmonary lesions was a better predictor than treatment records for BRD caused losses in ADG, the differences in growing phase final BW and ADG, combined with the observed high Hp concentrations and rectal temperatures observed at the time of treatment, indicate that administered treatments were related to infection in the present experiment. Therefore, while pulmonary lesion data are similar between BRD outcome categories, measuring finishing performance and carcass characteristics according to treatment for clinical signs is appropriate and relevant to the current ability of cattle feeders to classify BRD in the field.

Effect of BRD history on palatability and meat tenderness measures has been reported (Gardner et al., 1999; Roeber et al., 2001; Snowder et al., 2007). Generally, consistent with the present study, previous treatment for BRD was not associated with decreased tenderness. However, after 7 d aging, Gardner et al. (1999) observed increased WBSF in *longissimus* muscle from steers that exhibited respiratory tract lesions, but no differences were observed after 14 or 21 d aging. The tendency for decreased initial juiciness in strip steaks from heifers that had been classified as chronically ill during the growing phase may be related to the numerically lower marbling observed in those heifers. However, Roeber et al. (2001) showed no differences in palatability traits according to BRD treatment group even with a statistically significant decrease in marbling by treated animals. Similarly, Snowder et al. (2007) did not observe a significant correlation between respiratory disease and WBSF, or tenderness, juiciness, and flavor scores. However, no differences in marbling were observed in those cattle.

Conclusions

In the present experiment, clinical BRD resulted in decreased BW and ADG during the growing phase. However, after segregation according to previous BRD treatments during finishing, a compensatory response in ADG and G:F was observed in treated animals. Slaughter date selection for each BRD treatment group by objective and subjective measures was successful in reaching similar compositional end points between heifers that were never treated and those that required up to 3 BRD treatments. Days on feed required were similar for heifers that were never treated, treated one time, and treated two times, and approximately 18 additional days were required for heifers treated 3 times to have similar final live and carcass weights and carcass characteristics. Therefore, animals requiring multiple treatments for BRD maintain the potential to produce carcasses with similar value to healthy animals given the time and intake energy necessary. A ‘re-start’ program may be a viable alternative to ‘realizing’ or ‘railing’ chronically ill animals. Characteristics of retail shelf-life, tenderness, and palatability of meat are minimally affected by BRD treatment during the growing phase.

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Table 4.1. Composition of Growing and Finishing Diets (DM basis).

Item	Growing Diet	Finishing Diet
Dry rolled corn	45.0	68.0
Wet corn distillers grains w/solubles	15.0	20.0
Ground alfalfa hay	17.5	6.0
Ground prairie hay	17.5	-
B-157[1]	5.0	-
B-158[2]	-	6.0
Nutrient composition[3]		
Dry matter, %	72.3	67.8
Crude protein, %	14.1	15.6
NDF, %	30.7	17.3
ADF, %	18.9	8.2
Ca, %	0.75	0.74
P, %	0.39	0.43

[1]B-157 pelleted supplement contained (% of DM): ground corn, 69.6%; calcium carbonate, 20.0%; salt, 7.5%; urea, 5.83%; magnesium oxide, 2.0%; zinc sulfate, 0.300%; copper sulfate, 0.140%; manganous oxide, 0.100%; vitamin A (30,000 IU/g), 0.064%; vitamin E (50%), 0.044; Rumensin 80 (Elanco Animal Health, Indianapolis, IN), 0.25%.

[2]B-158 pelleted supplement contained (% of DM): ground corn, 29.11%; wheat middlings, 29.11%; calcium carbonate, 26.67%; salt, 6.25%; urea, 5.83%; magnesium oxide, 0.667%; zinc sulfate, 0.292%; copper sulfate, 0.083%; manganous oxide, 0.063%; vitamin A (30,000 IU/g), 0.053%; vitamin E (50%), 0.037; Rumensin 80 (Elanco), 0.313%; Tylan 40 (Elanco), 0.083%.

Table 4.2. Descriptive statistics of health data during the growing phase[1].

	Bovine Respiratory Disease Treatment Category[2]					
Item	0X	1X	2X	3X	C	Dead[3]
Number (%)	113 (33.53%)	100 (29.67%)	34 (10.09%)	39 (11.57%)	13 (3.86%)	27 (8.01%)
Treatment 1[4]						
DOF (S.D.)[5]		7.2 (7.1)	5.1 (5.8)	3.7 (3.3)	5.6 (5.7)	3.2 (2.5)
Range		0 to 30	0 to 22	-1 to 11	0 to 17	0 to 10
CAS (S.D.)[5]		1.3 (0.48)	1.47 (0.66)	1.59 (0.74)	1.50 (0.52)	1.79 (0.66)
Temp. (S.D.)[5]		105.8 (1.04)	106.1 (1.14)	106.2 (1.03)	106.4 (1.01)	106.6 (1.01)
Hp (S.D.)[5]		2.82 (2.57)	3.66 (2.70)	3.53 (2.57)	3.01 (1.97)	3.82 (3.06)
Treatment 2[4]						
DOF (S.D.)[5]			14.8 (9.2)	11.5 (5.5)	11.5 (6.9)	8.9 (4.4)
Range			4 to 42	5 to 24	5 to 23	5 to 24
CAS (S.D.)[5]			1.62 (0.74)	1.95 (0.74)	2.17 (0.94)	2.29 (0.85)
Temp. (S.D.)[5]			105.3 (0.85)	105.8 (0.88)	105.8 (0.99)	106.4 (1.15)
Hp (S.D.)[5]			2.64 (1.79)	3.99 (2.94)	2.63 (1.38)	2.97 (1.85)
Treatment 3[4]						
DOF (S.D.)[5]				20.7 (7.7)	17.2 (6.2)	14.3 (7.8)
Range				7 to 37	8 to 27	7 to 35
CAS (S.D.)[5]				1.80 (0.75)	1.92 (0.67)	1.95 (0.51)
Temp. (S.D.)[5]				105.2 (1.04)	105.3 (0.79)	105.7 (0.88)
Hp (S.D.)[5]				3.00 (2.72)	3.02 (1.97)	2.97 (1.85)
Removed[4]						
DOF (S.D.)[5]					34.1 (9.9)	27.9 (11.7)
Range					22 to 54	9 to 58
Dead[4]						
DOF (S.D.)[5]						30.9 (18.0)
Range						4 to 66

[1] Percentages calculated by dividing by the total number of heifers enrolled in the study (n=337). However, health outcome categories do not include animals removed from their home pens due to lameness (n=6, 1.78%) or heifers not included in the finishing phase due to treatment protocol non-compliance (n=5, 1.48%).

[2]BRD treatment category during the preconditioning phase: 0X = never treated; 1X = treated 1 time for signs of BRD; 2X = treated 2 times for signs of BRD, 3X = treated 3X for signs of BRD; C = deemed chronically ill; Dead = BRD mortalities.

[3]Of the 27 mortalities, 25 were case fatalities (Case fatality rate = 13.1%). Days on feed data include all animals who were treated at least 1, 2, or 3 times or were classified as chronically ill and subsequently died. Case fatalities occurred for cattle that were treated 1 (n = 4), 2 (n = 1), or 3 (n = 2) times and for calves classified as chronically ill (n = 18).

[4]Data reported according to the time each heifer received its first, second, or third antimicrobial treatment for bovine respiratory disease, was classified as chronically ill and removed from her home pen, or died.

[5]DOF = number of days on feed during the growing phase; CAS = clinical attitude score (0 to 4); Temp. = rectal temperature (°C), Hp = serum haptoglobin concentration (µg/mL).

Table 4.3. Finishing performance of heifers that received 0, 1, 2, or 3 treatments for Bovine Respiratory Disease or were deemed chronically ill during the preconditioning phase.

	BRD Treatment Category[1]							Significance of Contrast[2]		
Item[3]	0X	1X	2X	3X	C	SEM[4]	*P* > F[5]	L	Q	3 vs C
BW, kg										
Arr.	241	243	237	242	234	9.15	0.21	0.84	0.51	0.11
d 0	318	305	294	273	243	18.38	<0.001	< 0.001	0.01	< 0.001
d 28	374	362	356	329	283	18.90	<0.001	< 0.001	0.01	< 0.001
d 65	421	411	405	378	328	19.90	<0.001	< 0.001	0.005	< 0.001
d 122	492	485	482	457	414	17.23	<0.001	< 0.001	0.03	< 0.001
Final	537	532	527	535	506	10.59	0.056	0.58	0.18	0.01
Carc. Adj. [6]	541	532	527	534	493	12.40	0.02	0.41	0.21	0.007
ADG, kg/d										
Arr. to 0	1.14	0.92	0.86	0.46	0.13	0.17	<0.001	< 0.001	0.03	< 0.001
0 to 28	2.03	2.06	2.19	2.02	1.45	0.16	0.01	0.83	0.24	0.006
29 to 65	1.26	1.31	1.32	1.31	1.22	0.14	0.94	0.63	0.70	0.56
0 to 65	1.59	1.64	1.69	1.61	1.32	0.08	0.005	0.49	0.14	0.003
66 to 122	1.24	1.29	1.35	1.39	1.51	0.13	0.19	0.08	0.89	0.37
123 to end	1.35	1.16	1.11	1.32	1.36	0.15	0.30	0.17	0.24	0.80
0 to end	1.35	1.40	1.43	1.44	1.39	0.05	0.13	0.01	0.58	0.38
Arr. to end	1.29	1.26	1.26	1.18	1.06	0.06	<0.001	0.003	0.27	0.03
Adj. 0 to end[6]	1.37	1.39	1.43	1.44	1.32	0.07	0.50	0.14	0.88	0.18
Adj. Arr. to end[6]	1.31	1.26	1.27	1.18	1.01	0.06	0.002	0.01	0.55	0.03
DMI, kg/d										
0 to 28	8.79	8.49	8.54	7.28	6.52	0.52	<0.001	< 0.001	0.002	0.02
29 to 65	8.68	8.45	8.28	8.08	6.52	0.58	<0.001	0.02	0.94	<0.001
0 to 65	8.73	8.47	8.40	7.73	6.52	0.54	<0.001	< 0.001	0.18	< 0.001
66 to 122	9.11	9.24	9.02	9.04	7.87	0.43	0.075	0.64	0.79	0.02
123 – end	8.82	9.08	8.68	9.16	8.75	0.42	0.47	0.50	0.62	0.37

0 – end	8.89	8.90	8.69	8.60	7.63	0.40	0.007	0.13	0.75	0.007
DMI, % of BW[7]										
0 to 28	2.54	2.55	2.63	2.41	2.47	0.07	0.02	0.10	0.01	0.56
29 to 65	2.19	2.19	2.18	2.28	2.11	0.09	0.44	0.19	0.27	0.11
0 to 65	2.37	2.37	2.40	2.38	2.27	0.08	0.69	0.73	0.72	0.24
66 to 122	2.00	2.06	2.04	2.16	2.10	0.09	0.18	0.03	0.50	0.55
123 to end	1.71	1.79	1.72	1.84	1.90	0.06	0.02	0.03	0.47	0.41
0 to end	2.08	2.13	2.12	2.13	2.03	0.07	0.60	0.41	0.61	0.22
G:F										
0 to 28	0.231	0.243	0.257	0.278	0.220	0.022	0.017	0.002	0.66	0.01
0 to 65	0.183	0.193	0.203	0.210	0.201	0.013	0.005	< 0.001	0.70	0.40
66 to 122	0.136	0.140	0.150	0.153	0.201	0.017	0.003	0.07	0.95	0.005
123 to end	0.128	0.127	0.128	0.145	0.157	0.016	0.27	0.18	0.28	0.51
0 to end	0.152	0.157	0.165	0.168	0.186	0.009	0.001	0.002	0.83	0.04
Adj. 0 to end[6]	0.154	0.157	0.165	0.168	0.176	0.011	0.05	0.01	0.97	0.40

[1]BRD treatment category during the preconditioning phase: 0X = never treated; 1X = treated 1 time for signs of BRD; 2X = treated 2 times for signs of BRD, 3X = treated 3X for signs of BRD; C = deemed chronically ill.

[2]Significance of contrasts: L = linear effects of number of BRD treatments; Q = quadratic effects of number of BRD treatments; 3 vs. C = 3X vs. C heifers.

[3]Days on feed during the finishing phase. Arr. = arrival prior to preconditioning; End = day prior to slaughter. Cattle were slaughtered on d 152, 174, or 189 of finishing.

[4]Standard error of the Least squares means (n = 9 pens for 0X and 1X; n = 6 pens for 2X and 3X; n = 2 pens for C). Largest SEM shown.

[5]Probability of the overall F-test.

[6]Carcass adjusted BW calculated as HCW divided by average dressing percent for the study (63.33%). Adj. ADG and Adj. G:F calculated on a carcass adjusted basis.

[7]DMI expressed as a percent of mean BW during each interval period.

Table 4.4. Ultrasound estimates and carcass characteristics of heifers that received 0, 1, 2, or 3 treatments for Bovine Respiratory Disease or were deemed chronically ill during the preconditioning phase.

	BRD Treatment Category[1]						Significance of Contrast[2]		
Item	0X	1X	2X	3X	C	SEM[3]	*P* > F[4]	L	Q	3 vs C
Ultrasound Estimates										
LM area, cm^2										
d 65	82.7	79.4	77.9	77.1	61.9	4.94	<0.001	0.01	0.43	<0.001
d 122	88.4	87.1	86.0	86.1	76.8	3.93	0.05	0.31	0.69	0.02
IMF[5], %										
d 65	4.73	4.53	4.51	4.24	4.00	0.29	0.08	0.03	0.79	0.45
d 122	4.71	4.41	4.67	4.31	3.90	0.29	0.09	0.09	0.62	0.20
FT[6], cm										
d 65	0.92	0.85	0.86	0.71	0.52	0.06	<0.001	<0.001	0.22	0.005
d 122	1.05	0.99	0.97	0.87	0.67	0.07	<0.001	0.001	0.62	0.02
Carcass Characteristics										
DOF[7]	163	163	163	182	189	9.88	<0.001	<0.001	<0.001	0.007
HCW, kg	343	337	334	338	312	7.85	0.03	0.41	0.21	0.007
Dress., %	63.8	63.3	63.3	63.3	61.7	0.90	0.31	0.50	0.69	0.11
LM area, cm^2	77.5	77.7	77.9	81.4	75.3	3.38	0.46	0.15	0.36	0.13
FT[6], cm	1.48	1.40	1.35	1.34	1.14	0.15	0.24	0.16	0.61	0.22
KPH, %	1.99	1.94	1.90	1.82	1.95	0.13	0.51	0.13	0.64	0.12
Yield Grade	3.36	3.23	3.13	3.00	2.89	0.27	0.33	0.07	0.99	0.74
Marbling score[8]	480	461	446	440	399	28.7	0.10	0.06	0.68	0.22
Liver abscesses, %	10.7	15.9	2.4	4.7	9.8	11.11	0.25	0.10	0.87	0.54

[1]BRD treatment category during the preconditioning phase: 0X = never treated; 1X = treated 1 time for signs of BRD; 2X = treated 2 times for signs of BRD, 3X = treated 3X for signs of BRD; C = deemed chronically ill.

[2]Significance of contrasts: L = linear effects of number of BRD treatments; Q = quadratic effects of number of BRD treatments; 3 vs. C = 3X vs. C heifers.

[3]Standard error of the Least squares means (n = 9 pens for 0X and 1X; n = 6 pens for 2X and 3X; n = 2 pens for C). Largest SEM shown.

[4]Probability of the overall F-test.

[5]Intramuscular fat.

[6]12th-rib fat thickness.

[7]Days on feed during the finishing phase.

[8]300 = slight 0, 400 = small 0; 500 = modest 0.

Table 4.5. USDA grader assigned Yield Grade and Quality Grade distribution of heifers that received 0, 1, 2, or 3 treatments for Bovine Respiratory Disease or were deemed chronically ill during the preconditioning phase.

	BRD Treatment Category[1]							Significance of Contrast[2]		
Item	0X	1X	2X	3X	C	SEM[3]	*P* > F[4]	L	Q	3 vs C
Yield Grade[5]										
US 1, %	1.89	1.85	2.94	10.53	20.00	12.65	0.49	0.36	0.59	0.57
US 2, %	32.08	37.04	50.00	34.21	40.00	15.49	0.68	0.67	0.40	0.79
US 3, %	47.01	51.72	38.29	42.04	29.79	14.61	0.58	0.41	0.96	0.49
US 4, %	19.09	7.44	8.57	13.09	10.23	10.04	0.42	0.55	0.13	0.81
Quality Grade[5]										
US Choice, %	83.02	72.22	73.53	60.53	30.00	14.49	0.40	0.27	0.97	0.34
US Select, %	13.21	25.93	23.53	31.58	50.00	15.81	0.49	0.31	0.67	0.48

[1]BRD treatment category during the preconditioning phase: 0X = never treated; 1X = treated 1 time for signs of BRD; 2X = treated 2 times for signs of BRD, 3X = treated 3X for signs of BRD; C = deemed chronically ill.

[2]Significance of contrasts: L = linear effects of number of BRD treatments; Q = quadratic effects of number of BRD treatments; 3 vs. C = 3X vs. C heifers.

[3]Standard error of the Least squares means (n = 9 pens for 0X and 1X; n = 6 pens for 2X and 3X; n = 2 pens for C). Largest SEM shown.

[4]Probability of the overall F-test.

[5]Yield Grade and Quality Grade as determined by USDA graders.

Table 4.6. Distribution of pulmonary lesions of observed at slaughter from heifers that received 0, 1, 2, or 3 treatments for Bovine Respiratory Disease or were deemed chronically ill during the preconditioning phase[1].

	BRD Treatment Category[2]							Significance of Contrast[3]		
Item	0X	1X	2X	3X	C	SEM[4]	*P* > F[5]	L	Q	3 vs C
Overall, %	66.04	57.69	54.55	76.32	70.00	14.49	0.59	0.53	0.29	0.75
Severe, %	22.64	11.54	9.09	26.32	30.00	14.49	0.53	0.87	0.26	0.85
Missing, %	7.51	11.48	21.22	13.13	29.85	14.69	0.25	0.27	0.43	0.30
Adhered, %	20.75	21.15	29.39	26.32	20.00	12.65	0.60	0.46	0.54	0.75
Left, %	50.94	40.38	48.48	60.53	60.00	15.49	0.63	0.47	0.38	0.98
Right, %	39.62	32.69	27.27	52.63	20.00	12.65	0.51	0.51	0.28	0.33

[1]Lungs scored at chain speed in the plant using a scoring procedure based on that of Bryant et al. (1999)

[2]BRD treatment category during the preconditioning phase: 0X = never treated; 1X = treated 1 time for signs of BRD; 2X = treated 2 times for signs of BRD, 3X = treated 3X for signs of BRD; C = deemed chronically ill.

[3]Significance of contrasts: L = linear effects of number of BRD treatments; Q = quadratic effects of number of BRD treatments; 3 vs. C = 3X vs. C heifers.

[4]Standard error of the Least squares means (n = 9 pens for 0X and 1X; n = 6 pens for 2X and 3X; n = 2 pens for C). Largest SEM shown.

[5]Probability of the overall F-test.

Table 4.7. Visual and instrument attributes of strip loin steaks from heifers receiving 0, 1, 2, or 3 treatments for BRD or heifers deemed chronically ill during the growing phase.

	BRD Treatment Category[1]							Significance of Contrast[2]		
Item	0X	1X	2X	3X	C	SEM[3]	*P* > F[4]	L	Q	3 vs C
Color[5]	4.49	4.65	4.25	4.11	3.93	0.40	0.03	0.01	0.27	0.54
Discoloration[6]	3.06	3.04	3.51	2.97	2.75	0.00	0.06	0.74	0.07	0.49
Appearance[7]	4.04	4.15	3.67	3.63	3.78	0.48	0.10	0.02	0.64	0.68
L*[8]	40.59	41.36	40.82	41.59	40.80	1.22	0.48	0.35	0.99	0.48
a*[9]	16.42	16.50	15.20	15.78	16.37	1.00	0.16	0.11	0.57	0.54
b*[10]	16.62	16.83	16.14	16.41	15.98	0.52	0.22	0.26	0.91	0.42

[1]BRD treatment category during the preconditioning phase: 0X = never treated; 1X = treated 1 time for signs of BRD; 2X = treated 2 times for signs of BRD, 3X = treated 3X for signs of BRD; C = deemed chronically ill.

[2]Significance of contrasts: L = linear effects of number of BRD treatments; Q = quadratic effects of number of BRD treatments; 3 vs. C = 3X vs. C heifers.

[3]Standard error of the Least squares means (n = 9 pens for 0X and 1X; n = 6 pens for 2X and 3X; n = 2 pens for C). Largest SEM shown.

[4]Probability of the overall F-test.

[5]Meat color: 1 = extremely dark red, 8 = extremely bright cherry red.

[6]Surface discoloration: 1 = total discoloration (100%), 7 = no discoloration (0%).

[7]Overall appearance: 1 = extremely undesirable, 8 = extremely desirable.

[8]Brightness: 0 = black, 100 = white.

[9]Redness/greenness: positive values = red, negative values = green.

[10]Yellowness/blueness: positive values = yellow, negative values = blue.

Table 4.8. Warner-Bratzler Shear Force (WBSF) and sensory characteristics of strip loin steaks from heifers that received 0, 1, 2, or 3 treatments for Bovine Respiratory Disease or were deemed chronically ill during the preconditioning phase.

	BRD Treatment Category[1]							Significance of Contrast[2]		
Item	0X	1X	2X	3X	C	SEM[3]	*P* > F[4]	L	Q	3 vs C
WBSF, kg	2.82	2.83	2.79	2.88	2.72	0.11	0.65	0.52	0.44	0.18
Init. Juiciness[5]	5.40	5.45	5.39	5.43	5.10	0.23	0.06	0.96	0.89	0.009
Sust. Juiciness[6]	5.47	5.48	5.50	5.50	5.21	0.30	0.21	0.69	0.82	0.03
Tenderness[7]	6.02	6.08	6.03	6.04	6.13	0.27	0.70	0.99	0.50	0.37
Conn. Tissue[8]	6.49	6.47	6.52	6.35	6.50	0.35	0.15	0.08	0.10	0.15
CBF[9]	2.42	2.37	2.34	2.36	2.34	0.18	0.42	0.18	0.26	0.70

[1]BRD treatment category during the preconditioning phase: 0X = never treated; 1X = treated 1 time for signs of BRD; 2X = treated 2 times for signs of BRD, 3X = treated 3X for signs of BRD; C = deemed chronically ill.

[2]Significance of contrasts: L = linear effects of number of BRD treatments; Q = quadratic effects of number of BRD treatments; 3 vs. C = 3X vs. C heifers.

[3]Standard error of the Least squares means (n = 9 pens for 0X and 1X; n = 6 pens for 2X and 3X; n = 2 pens for C). Largest SEM shown.

[4]Probability of the overall F-test.

[5]Initial juiciness: 1 = extremely dry, 8 = extremely juicy.

[6]Sustained juiciness: 1 = extremely dry, 8 = extremely juicy.

[7]1 = extremely tough, 9 = extremely tender.

[8]Connective tissue: 1 = abundant, 8 = none.

[9]Cooked beef flavor: 1 = not detectable, 3 = strong.

CHAPTER V

DIETARY ADAPTATION METHOD EFFECTS HEALTH AND FEEDLOT PERFORMANCE OF NEWLY RECEIVED STEER CALVES

ABSTRACT: An experiment was conducted to evaluate receiving and adaptation programs on health, performance and carcass merit of high-risk calves program-fed a high-concentrate diet during the growing phase. Five hundred thirty-six steer and bull calves (initial BW = 283 ± 21.1 kg) were delivered to the Willard Sparks Beef Research Center, Stillwater, OK from auction markets in Florida, Missouri, Oklahoma, and Texas during November and December 2006. Calves were adapted to an 88%-concentrate diet traditionally using ad libitum intake of 3 transition diets over 21 days (TRAD); were fed the 64%-concentrate diet for 28 d before being transitioned traditionally (REC); were adapted traditionally using these same diets, but for each transition diet, intake was limited to 2.1, 2.3, and 2.5 times the initial maintenance energy requirements (LMI); or were program fed the final 88%-concentrate diet from d 1 through the end of the experiment (PF). After dietary adaptation, all calves were program-fed for a targeted ADG of 1.13 kg/d. Results suggested that feeding a higher-roughage diet for an extended period (28 d) after arrival (REC) resulted in the greatest ADG ($P = 0.001$) during the growing period and program-feeding a high-concentrate diet from d 1 resulted in the least ADG. However, when REC cattle were adapted to a high-concentrate, program-fed diet,

they were less efficient ($P = 0.03$) than TRAD, LMI, or PF steers ($P = 0.03$). Bovine respiratory disease (BRD) morbidity and the percent of steers that required 3 antimicrobial treatments for BRD tended ($P = 0.08$) to be 33% greater for steers on TRAD and PF treatments than REC and LMI. Following the growing period, 141 steers were retained and observed through finishing and slaughter. Finishing performance was not affected ($P \geq 0.15$) by adaptation treatment. However, HCW was greatest for REC and TRAD, intermediate for LMI, and least for PF steers ($P = 0.04$); no other differences in carcass characteristics were observed ($P \geq 0.22$). Extending the period during which a higher roughage diet is fed or limiting maximum intake during the adaptation period can reduce morbidity in newly received feedlot steers. However, extended ad libitum feeding of a higher-roughage diet can result in decreased efficiency of steers when adapted to a program-fed, high-concentrate diet.

Key words: bovine respiratory disease, diet adaptation, high-risk calves, morbidity, programmed feeding, roughage levels

INTRODUCTION

Until the recent increase in the price of corn, the prevalence of calves placed in feedlots was increasing in most feedlots; this increased the risk for morbidity and mortality. There has been debate over the degree of impact that diet formulation and management can have on morbidity and mortality. Rivera et al. (2005) suggested that performance is lost equal to approximately $20/animal by feeding 40% compared with 100% roughage. In their review, morbidity of lightweight, highly stressed cattle due to bovine respiratory disease (**BRD**) was decreased when roughage concentration in the diet was increased. However, the change was small, and the authors concluded that the disadvantage in average daily gain (**ADG**) and dry matter intake (**DMI**) that occurs when cattle are fed greater roughage concentrations in receiving diets likely would be offset by favorable effects of increased roughage concentration on BRD morbidity. Anecdotal information indicates that higher morbidity in the starting period often results in a higher incidence of morbidity later in the feedlot, and that feeding a higher-roughage starting diet (40 to 45% roughage) may decrease the incidence of morbidity throughout the feeding period.

The California Net Energy System has allowed cattle feeders to prescribe rate of gain of cattle by feeding energy to meet requirements for maintenance and gain (Galyean, 1999). In growing programs, especially, a high-concentrate diet can be fed at levels less than ad libitum for targeting specific rates of gain. This allows cattle to be grown at lower rates without using high levels of roughages in the diet. Traditionally, roughages are more expensive per unit energy than concentrates (Eng, 1995). In regards to the finishing phase, different methods of adapting cattle to high-concentrate diets have been

investigated (Bartle and Preston, 1992; Choat et al., 2002) and the results reviewed (Brown et al., 2006). Limiting maximum intake when feeding a series of diets that decrease in the fraction of roughage has resulted in comparable or improved performance over cattle offered the same diets ad libitum. Choat et al. (2002) fed the final finishing diet (90% concentrate) at restricted levels or traditional adaptation diets to yearling steers during the adaptation period and reported decreased DMI by the restricted steers resulting from less feed offered during adaptation. However, overall daily gain was not affected by treatment. In Exp. 2 of the same report (Choat et al., 2002), similar adaptation programs were fed to calves. Restricted calves had lower rates of gain and decreased DMI compared with traditionally adapted calves. Feed efficiency was not different, although ad libitum intake of the final diet by the restricted calves did not approach that of the ad libitum calves until d 40 of the trial. In the previously mentioned studies (Bartle and Preston, 1992; Choat et al., 2002; Brown et al., 2006), BRD incidence was not reported. The purpose of this experiment was to evaluate receiving and adaptation programs on growth and health performance of newly received, high-risk calves program-fed a high-concentrate diet during the growing phase as well as finishing performance and carcass characteristics.

MATERIALS AND METHODS

Cattle and Experimental Design

Steer and bull calves (n = 536 with an initial BW = 283 ± 21.1 kg) were assembled at auction markets in Florida, Missouri, Oklahoma, and Texas during November and December 2006 and delivered to the Willard Sparks Beef Research Center, Stillwater,

OK (Table 5.1). Upon arrival, calves were allowed to rest at least 1 h without access to feed or water prior to initial processing. This included recording individual body weight (**BW**), identification using an individually numbered ear tag, verification of sex, and collecting an ear notch for the detection of animals persistently infected with bovine viral diarrhea virus (**PI-BVDV**) using immunohistochemistry (Oklahoma Animal Disease Diagnostic Laboratory, **OADDL**). After initial processing through initiation of the experiment, calves were maintained in pens with ad libitum access to long-stemmed prairie hay. Both prior to and throughout the study, pens used were 12.2 × 30.5 m with a 12.2 m fence-line concrete feed bunk. Automatic water basins located along the fenceline were shared by two adjacent pens. Processing occurred on the day of arrival or up to 5 days after arrival. At processing, calves were vaccinated against viral respiratory pathogens including infectious bovine rhinotracheitis (**IBR**), bovine viral diarrhea virus (**BVDV**; Types I and II), bovine parainfluenza-3 (**PI3**), and bovine respiratory synctial virus (**BRSV**; Vista 5, Intervet/Schering-Plough Animal Health, DeSoto, KS), given a clostridial bacterium/toxoid (Vision 7, Intervet/Schering-Plough Animal Health), administered both oral (Safeguard, Intervet/Schering-Plough Animal Health) and topical (Ivomec Pour-On, Merial, Duluth, GA) dewormers, and implanted with zeranol (Ralgro, Intervet/Schering-Plough Animal Health). Bulls were surgically castrated, and dehorning was done when necessary. Steers were re-vaccinated (Vista 5) on d 11 after beginning the trial.

The experiment was a completely randomized block design including 4 treatments and 6 replications/treatment for a total of 24 pens holding 20 to 24 calves/pen. Four diets with increasing concentrate levels (64, 72, 80, and 88% concentrate; Table 5.2 and Table

5.3) were fed during the adaptation to the high-concentrate diet and the subsequent growing phase. During the growing phase of the experiment, calves were fed to a similar target BW (NRC, 2000). This target weight was calculated as initial BW plus 68 kg (ADG of 1.13 kg/d for 60 d).

Cattle arrived in truckloads during the dates shown in Table 5.1. When a sufficient number of steers was assembled to fill 4 or 8 pens (20 to 24 steers/pen; lot), steers were stratified by arrival BW and assigned to pens. When enough steers were received to fill 8 pens, steers were blocked by weight into 2 weight blocks (Lots 1 and 4). Within block, steers were then arranged by ascending BW within sex (steer or bull on arrival) and arrival date and randomly assigned to 4 pens, assuring homogeneity among groups within and among pens. Steers were weighed and allotted to pens on d 1 for each lot. The length of time between calf arrival or processing and trial initiation was between 0 and 11 or 0 and 6 days, respectively. Steers were again weighed on d 22, 43, 59, and on consecutive days at the end of the trial (d 78, 76, 62, and 59 for loads 1, 2, 3, and 4, respectively; Table 5.1).

Dietary Adaptation Programs

A timeline for when experimental diets were fed and the intake was allowed on each diet is shown in Table 5.3. Experimental treatments included: 1) **TRAD**; the three adaptation diets (Table 5.2) were offered ad libitum for 7 to 8 d intervals until d 22. On d 1, 1.25% (as-fed) of initial BW of the 64% concentrate diet was offered with feed supply increasing 0.68 kg/steer daily when no feed remained in the bunk. The final diet was offered on d 21 with intake restricted such that cattle would attain their final target weight

on day 60; 2) **REC**; the 64% concentrate diet was offered free choice during a 28-d receiving period followed by traditional adaptation using a series of diets with increasing concentrate levels fed for 7-d intervals (72 and 80% concentrate, respectively). The final diet (88% concentrate) was initially offered on d 43. Bunk management during the 43-d adaptation period was the same as TRAD; 3) **LMI**; the four adaptation diets were offered such that maximum metabolizable energy (**ME**) intake was restricted to 2.1, 2.3, and 2.5 times that required for maintenance during wk 1, 2, and 3, respectively (Bartle and Preston, 1992). Net energy required for maintenance was calculated using initial BW. The final diet was fed on d 21; and 4) **PF**; the 88% concentrate diet was offered d 1. The ME delivery/steer was equivalent to TRAD calves initially. However, when no feed remained in the bunk, feed delivered was increased 0.23 kg/steer daily until the amount of feed delivered reached that required for the calves to gain to the target weight.

Based on BW of steers on d 1 (for PF), d 21 (for TRAD, REC, PF) and d 42 for all treatments, steers were program fed so they reached their target weights on d 60. Net energy required for maintenance and gain were calculated using the expected mean BW for each pen for each period. Final shrunk BW was assumed to be 544 kg for all steers, and 478 kg was the standard reference weight used to calculate equivalent shrunk BW (NRC, 2000). Steers were fed twice daily at approximately 0700 and 1000 in the morning throughout the trial. Diets were mixed and fed in a 2,377 or a 5,207 L trailer mounted feed mixer (Roto-Mix 84-8 or Roto-Mix 184-8; Roto-Mix, Dodge City, KS) depending on relative batch size for each ration. Batch sizes and mixers used were evaluated daily to maximize overall facility efficiency. Bunks were evaluated twice daily and feed deliveries were called so that approximately 10% orts remained prior to feeding

each morning during the ad libitum periods for TRAD and REC. Bunks were swept and remaining feed was weighed weekly, and if necessary, throughout the remainder of the experiment. Diet samples were collected twice each week and composited within diet and weigh period. Proximate analyses were conducted on composite diet samples (Servi-Tech Laboratories, Dodge City, KS). One day prior to weighing cattle on d 22 cattle on TRAD, REC, and LMI treatments were fed 50% of the previous day's feed allotment in order to minimize the effect of gastrointestinal fill compared to PF steers. Similarly, on d 42, REC cattle were again shrunk to reduce gastrointestinal fill effects for the d-43 BW compared to the other three treatments that were being program-fed a high-concentrate diet.

Fecal Samples

Six animals per pen were randomly selected for fecal sample collection. On d 11, 22, 42, and 59, a fecal grab sample was collected via rectal palpation and pH was measured on the grab sample using a portable pH meter equipped with a soil probe (VWR International, West Chester, PA). In addition, fecal consistency was scored according to a system adapted from Larson et al. (1977) and Ireland-Perry et al. (1992). Samples, evaluated visually and by handling, were given a score from 1 to 5. Scores were described as follows: 1) firm, hard, and dry appearance, as typical of a cow feeding on dry range; 2) slightly less firm and hard with more moisture – comparable to cookie dough; 3) relatively soft and moist – generally included anything between the scores of 2 and 4; 4) loose, very moist, and runny, but could still be held in one's hand – comparable

to pancake batter; 5) very thin and watery and could not be captured in an open hand – comparable to orange juice.

Animal Health

Each morning, steers were evaluated for signs of BRD by trained personnel according to standard protocol for the facility (Step et al., 2008). Signs of disease included depression (hanging head, sunken of glazed eyes, altered gate); abnormal appetite (completely off feed, eating less than or with less aggression than penmates, lack of fill or obvious BW loss); respiratory signs (obvious labored breathing, extended head and neck, or noise when breathing); and nasal or ocular discharge. Any calf exhibiting one or more of these signs was assigned a severity score of 1 (mild), 2 (moderate), 3 (severe,) or 4 (moribund) and pulled to the chute for further evaluation which included measuring rectal temperature (GLA, M-500, GLA Electronics, San Luis Obispo, CA). Steers with a severity score of 1 or 2 were administered antimicrobials only when the rectal temperature was $\geq$ 40.0ºC, and steers with a 3 or 4 were treated regardless of rectal temperature. Steers were treated with antimicrobials according to a standard feedlot protocol which included 2.5 mg tulathromycin per kg BW (Draxxin, Pfizer Animal Health, Exton, NY) initially, followed by 40 mg florfenicol per kg BW (Nuflor, Intervet/Schering-Plough Animal Health, DeSoto, KS) for a second pull, and two doses of ceftiofur (2.2 mg/kg BW; Excenel, Schering-Plough Animal Health, Kenilworth, NJ) given 48 h apart for a third pull. After receiving all three therapies, when condition consistently decreased, steers were removed from their home pens for animal welfare reasons. Steers were also examined and treated for other medical conditions when necessary.

Finishing Phase

After the final BW from the growing phase were collected (February 5 and 6, 2007), 384 steers were selected and used for another experiment at the facility. The remaining 141 steers were stratified by BW within adaptation treatment, blocked into three weight blocks, and assigned to pens for finishing (n = 3 pens/treatment). Steers were implanted with trenbolone acetate and estradiol (Revalor-S; Invervet/Schering-Plough Animal Heatlh) at the beginning of the finishing phase. Pens used were 12 of the same 24 pens used in the growing phase as described above. Feed offered was increased gradually over 7 d until ad libitum intake was achieved while feeding the 88%-concentrate diet used for program feeding in the growing phase. On d 13, steers were switched to a 94%-concentrate finishing ration (Table 5.2). Diets were mixed and delivered as described above, except that the second feeding was begun at 1330 h daily. Bunks were evaluated once daily for orts and managed so that little or no feed remained in the bunk each morning. However, steers were challenged in intake at least every third day. Pens were weighed using a group platform scale on d 60, and steers were weighed individually one day prior to slaughter on d 104, 134, and 167 for blocks 1, 2, and 3, respectively. Steers were slaughtered at a commercial abattoir where trained personnel from Oklahoma State University recorded hot carcass weight (**HCW**), *longissimus* muscle (**LM**) area, 12th-rib fat thickness, estimated percent internal fat (**KPH**), marbling score, and calculated yield grade.

Calculations and Statistics

For the growing phase, performance variables including BW, ADG, DMI, and the ratio of ADG:DMI (**G:F**) were calculated on a pen basis. Growing phase BW were not shrunk, except as described above, but d 60 and final BW during the finishing phase were shrunk 4%. Additionally, DMI was calculated as a percent of average BW for each period of interest and ME intake was calculated for each pen using measured DMI and dietary ME (NRC, 2000). The ratio of ADG (g/d) to ME was also calculated. Carcass adjusted final BW was calculated by dividing the final BW for each pen by the average dressing percentage for each block, respectively. Continuous data were analyzed as a completely randomized block design with pen as the experimental unit using the MIXED procedure of SAS (SAS Institute, Cary, NC). The model statement contained the fixed effect of adaptation treatment. All pens that began treatments on the same day were classified as a lot, and the random statement contained lot and weight block within lot. Morbidity data including total morbidity, retreats as a percent of total morbidity, the number of first, second, and third treatments, mortality, and case fatality rate were analyzed as binomially distributed using the GLIMMIX procedure of SAS with the default logit link assumed. The model listed above was used. Least squares means were calculated and the ilink option was used to estimate frequencies and standard errors.

Fecal pH and score data were analyzed as repeated measures with steer as the experimental unit using the MIXED procedure of SAS. Treatment, day, and the treatment × day interaction were included in the model with lot and weight block within lot in the random statement. Multiple covariance structures were evaluated and a heterogeneous compound symmetry structure was selected as it yielded the smallest

Akaike and Schwarz Bayesion criterian base on the -2 residual log likelihood while estimating the fewest covariance parameters.

For the finishing phase, performance data were similarly analyzed using the MIXED procedure of SAS. Treatment was included in the model statement and weight block was considered a random effect. The Kenward-Rogers option was used to calculate corrected denominator degrees of freedom for all analyses. Differences were considered significant when $P \leq 0.05$ and as tendencies when $0.05 < P \leq 0.10$.

RESULTS

Performance

The frequency of slick feed bunks for each treatment (d 1 to 43) are shown in Table 5.3. Both LMI and PF pens had greater ($P < 0.001$) occurrence of slick bunks during week 1, followed by REC, with TRAD least. As expected, PF pens had the most ($P < 0.001$) slick bunks during d 8 to 14 and 15 to 22, followed by LMI. Traditionally adapted and REC pens had similar frequencies of slick bunks during d 8 to 14 and 15 to 22. After d 23, when TRAD and LMI steers joined PF steers on the 88% program-fed diet, no orts were observed in their feedbunks on any day throughout the rest of the trial. Similarly, REC pens left no feed remaining for any pen after transitioning to a program-fed diet (d 43 to end). Growth performance results are shown in Table 5.4. Steers fed according to the four adaptation treatments had similar BW ($P = 0.58$) on d 22 and ADG from d 1 to 22 ($P = 0.41$). However, from d 23 to 43, REC steers gained faster ($P > 0.001$) and therefore weighed more ($P < 0.001$) than steers on the other three treatments, whose BW and ADG was similar ($P > 0.10$). By d 59, the advantage in BW for the REC steers

compared to TRAD and LMI steers was diminished. Steers fed a 64% concentrate diet for 28 d prior to adaptation tended to weigh more than LMI steers (352 vs. 347 kg; P = 0.06) and both TRAD and REC tended (P = 0.06) to weigh more than PF steers (350 and 352 vs. 345 kg, respectively). From d 44 to 59, TRAD, LMI, and PF gained faster (P < 0.001) than REC steers. At the end of the growing phase, BW was greatest for REC followed by TRAD and LMI and least for PF. When considering ADG across the entire adaptation period (d 1 to 43), similar to d 23 to 43 ADG, REC steers had an advantage to the other adaptation treatments. From d 43 to end, TRAD, LMI, and PF steers had all been program-fed the 88% concentrate diet for at least 17 d. During that period, steers in those three treatments gained slightly less daily than expected (1.05 vs. 1.13 kg/d). However, rate of gain was 60% greater (P < 0.001) than REC steers. Across the entire growing phase, ADG for REC steers was greatest (P = 0.001), followed by TRAD and LMI, with PF steers having the lowest ADG.

As expected, through the first 22 d, PF steers consumed less dry matter (**DM**) than the other three treatments (P < 0.001). However, LMI had similar (P > 0.10) DMI to TRAD steers throughout the adaptation period (d 1 to 22), and this DMI was also similar to REC steers, who were given only the 64% concentrate diet during that time. From d 22 to the end of the growing period, and overall from d 1 to 43 and d 1 to end REC steers had greater (P < 0.001) DMI than TRAD, LMI, and PF. This was by design as REC steers were allowed ad libitum intake compared to the programmed intakes of PF from d 1 to 43 and TRAD and LMI from d 22 to 43. Dry matter intake, expressed as a percent of BW from d 43 to end was similar for all treatments and averaged 1.85% of BW (P = 0.31). Similarly, when each diet was expressed on a total kg/steer basis through the first

60 d (Table 5.5), REC steers consumed the most ($P < 0.001$) of the three adaptation rations and total DM; however, due to the shorter time fed, REC steers' consumption of the 88% concentrate ration was the least ($P < 0.001$). Again TRAD and LMI steers consumed similar ($P > 0.10$) amounts of each of the three adaptation diets and the final diet.

The ratio of ADG to DMI was not different ($P \geq 0.15$) across dietary adaptation treatments through 43 days (Table 5.4). However, after REC steers were restricted from ad libitum to program-fed on d 44 to 59 and 44 to end, their G:F were approximately 36% ($P < 0.001$) and 85% ($P = 0.057$) of other treatments, respectively. Overall G:F was greatest ($P < 0.01$) for TRAD and PF, intermediate for LMI, and least for REC.

Because steers among the four treatments consumed different amounts of DM (by design) of the four different diets, intake of ME and the ratio of ADG:ME intake was calculated (Table 5.6). Following the trend of DMI, ME intake was similar ($P > 0.10$) across TRAD, REC, and LMI treatments from d 1 to 22, but less ($P = 0.002$) for PF steers during that time period. Across the rest of the trial REC steers generally consumed more ($P < 0.002$) energy than the other groups, while TRAD and LMI were intermediate and PF least. No differences ($P \geq 0.31$) in ADG:ME intake were observed from d 1 to 22 or 23 to 43. However, analyzed across the first 43 d, REC steers were more ($P = 0.004$) efficient at utilizing intake energy than the other three treatments. As noted in G:F data, REC steers were significantly less ($P < 0.001$) efficient utilizers of intake energy during the final days of the growing period, but unlike G:F, no differences ($P = 0.38$) in the efficiency of ADG:ME intake were observed from d 1 to end.

Fecal Samples

Fecal pH and consistency score data from the samples collected are shown in Figure 5.1. For fecal pH, there was a tendency for an adaptation treatment × day interaction ($P = 0.06$). This was because REC steers had numerically lower ($P = 0.11$) pH (6.30) followed by LMI and PF (6.47 and 6.49, respectively) and TRAD (6.58) on d 59. There was a significant day effect ($P < 0.001$), with mean pH across treatments greater on d 11 and 22 (6.58) than d 43 (6.44) and 59 (6.47). No other differences ($P = 0.85$) according to adaptation treatment in fecal pH were observed. However, overall fecal pH was decreased ($P = 0.001$) on d 43 (6.44) and 59 (6.47) compared to d 11 (6.58) and 22 (6.58). Similarly, fecal scores decreased ($P < 0.001$) over time. Mean fecal scores were 3.4, 3.1, 3.0, and 3.0 on d 11, 22, 43, and 59, respectively. No adaptation treatment effect or day × adaptation treatment interaction ($P \geq 0.21$) were observed in fecal scores.

Animal Health

Across treatments the number of steers treated at least once for signs of respiratory disease was 201 (37.5%), and 43 required more than one antimicrobial treatment (21.4% retreatment rate). Ten steers died, or required euthanasia, during the experiment (1.9%), and the case fatality rate was 3.4%. No morbidity or mortality attributable to digestive causes was observed during the trial. Morbidity and mortality according to adaptation treatment is reported in Table 5.7. There was a tendency ($P = 0.08$) for total morbidity rates to be lower for REC and LMI steers than TRAD and PF, and compared to TRAD, the odds ratios for total morbidity rate were 0.68 and 0.59 for REC and LMI, respectively. No differences ($P \geq 0.34$) in retreatment rate, or the number of steers

treated 1 or 2 total times were observed. However, the number of steers that required 3 total BRD treatments tended ($P = 0.07$) to be least for REC and LMI, intermediate for TRAD, and greatest for PF steers. No differences ($P \geq 0.40$) were observed in total mortality or case fatality rates. Steers fed according to the LMI adaptation protocol received their first treatment, on average, on d 7, followed by PF and TRAD on d 9.4 and 11.0, respectively. Steers fed the 64% concentrate ration tended ($P = 0.09$) to receive initial treatment the latest (d 13).

Finishing Phase Performance and Carcass Characteristics.

The final BW after the growing phase when including all 24 pens was greatest ($P = 0.005$) for REC and TRAD, intermediate for LMI, and least for PF steers. After the steers were re-allocated to finishing pens, the mean BW for the 4 treatments ranked the same, though were not different ($P = 0.27$) among treatments. On d 60, PF steers tended ($P = 0.08$) to weigh less than REC steers. Carcass adjusted final BW was greatest ($P = 0.04$) for REC, intermediate for TRAD and LMI, and least for PF. However, no differences ($P \geq 0.25$) in ADG, DMI, expressed as kg/d or as a percent of BW, or G:F were observed. With the exception of HCW, no differences ($P \geq 0.22$) in carcass characteristics were seen (Table 5.9). Hot carcass weight was greatest ($P = 0.04$) for REC, intermediate for TRAD and LMI, and least for PF steers.

DISCUSSION

Performance

The adaptation programs used in this experiment have been evaluated before, but in published reports ad libitum use of step-up diets was compared separately to either limiting maximum intake (Xiong et al., 1991; Bartle and Preston, 1992) or restricted feeding of a 90 to 92.5% concentrate diet (Bierman and Pritchard, 1996; Weichenthal et al., 1999; Choat et al., 2002). Those experiments, in contrast to the present experiment, used primarily yearling cattle to examine adaptation to a finishing diet, which was fed ad libitum. Xiong et al. (1991) suggested that controlling peaks in DMI could be accomplished by using multiples of maintenance energy requirements to provide an upper limit of feed intake. Their goal was not to reduce or program intake. They conducted an experiment in which intake was restricted to 2.3 2.5, and 2.7 times maintenance during weeks 1 through 3 of adaptation followed by 2.9 times maintenance through finish compared with normal ad libitum bunk management in a factorial arrangement with roughage concentration (9 of 18% of DM) and three densities of steam-flaked sorghum. Xiong et al. (1991) noticed an interaction, in which steers fed intake limited by multiples of maintenance gained more than steers fed ad libitum through 56 d on the 9% roughage treatments, but limited intake steers gained less than ad libitum when fed 18% roughage. Over the entire finishing phase, steers fed 18% roughage ad libitum gained more than those limited by maintenance, while no difference in ADG for 9% roughage diets was noticed due to feeding management. This discrepancy was driven by increased DMI for ad libitum steers consuming 18% roughage compared to limited steers, while limited and ad libitum steers had similar DMI of a 9% roughage diet. No

difference in G:F was noted (Xiong et al., 1991). In a similar experiment, Bartle and Preston (1992) restricted intake of yearling steers based on multiples of maintenance using two programs (2.1, 2.3, 2.5, and 2.7 [2.7MM] or 2.3, 2.5, 2.7, 2.9 [2.9MM] times maintenance requirements during weeks 1, 2, 3, and 4, respectively) vs. ad libitum. Again, daily intake through finish was limited according by the greatest multiple of maintenance amount for each treatment. In their experiment, DMI decreased 4.7 and 5.8% for 2.7MM and 2.9MM compared to ad libitum, respectively, during the adaptation period, which is inconsistent with the present experiment in which TRAD and LMI steers had similar DMI for each period during the growing phase. The 2.7MM steers also had numerically increased ADG and a tendency for greater G:F (Bartle and Preston, 1992). Over the entire experiment, 2.7MM tended to improve ADG 6% and G:F 4% compared with ad libitum steers while 2.9MM was intermediate. In the present experiment, ADG and G:F were not different between TRAD and LMI during the growing phase. However, when efficiency was expressed as ADG:ME intake TRAD steers were more efficient from d 43 to end during the program-fed period. Bartle and Preston (1992) reported that, although DMI was less for 2.7MM ad libitum steers during the adaptation phase, DMI was greater from d 64 to finish. Across the feeding period ADG tended to be improved for the 2.7MM steers, while DMI was similar. Therefore 2.7MM steers tended to have an advantage in overall G:F. In the present experiment, since both TRAD and LMI treatments were program-fed to have the same rate of gain during the growing phase, a compensatory intake response was not possible, perhaps causing the inefficiencies observed for LMI compared TRAD steers.

The other primary method that has received attention, compared to ad libitum feeding, is limit-feeding the high-concentrate diet initially. Bierman and Pritchard (1996) and Weichenthal et al. (1999) observed a 6 to 10% decrease in overall DMI and a 7.8 to 13% improvement in feed efficiency for yearling cattle started on a high-concentrate diet with a limited intake on d 1 compared with ad libitum step-up diets. Similarly, Choat et al. (2002) observed decreased DMI of yearling steers adapted using restricted feeding of the final diet, as well as 3.8% decreased ADG. This was due to a 27% decrease in ADG from d 0 to 28 despite a compensatory response in restricted steers from d 57 to 70. Combined with the lower DMI, efficiency was similar between treatments in that experiment. In Exp. 2 of the same report (Choat et al., 2002), steer calves had lower adaptation period and overall DMI and ADG when restricted intake of the final diet compared to ad libitum adaptation programs. Consistent with these reports, in the present experiment PF steers consumed less DM (42% less than TRAD) during the first 22 d. However, ADG and G:F were not different. After TRAD and LMI were switched to program-fed, ADG and DMI were not different among these treatments. Although overall ADG was least for PF, energy efficiency was greatest.

Similar to the present study, in which cattle from all-treatments were program-fed after dietary adaptation, Xiong et al. (1991), Bartle and Preston (1992), and Bierman and Pritchard (1996) managed cattle according to a their respected limited maximum intake, or prescribed intake protocols through finishing. However, in the experiments of Weichenthal et al. (1999) and Choat et al. (2002), cattle were allowed ad libitum intake following adaptation through finishing. Yearling steers reached ad libitum intake within 3 weeks (Weichenthal et al., 1999) or 36 days (Exp. 1; Choat et al., 2002) with no

reported interruptions in rate of DMI increase. However, calves of Exp. 2 (Choat et al., 2002) showed more variation in the rate of DMI increase, including a plateau in intake during the 4th week, and equivalent DMI with traditionally adapted cattle was not reached until nearly day 50. Choat et al. (2002) concluded that the decreased performance in the calves was due to a longer than desired restriction in intake energy. In the present study, PF cattle had reached their program-fed intake by d 22, and it is not known whether rate of DMI increase would have plateaued similarly to the calves of Choat et al. (2002).

Based on experience feeding similar receiving diets (60 to 65% concentrate) in the facility, we expected the REC steers to gain approximately 1.13 kg/d during the first 28 d. For this reason we chose a similar programmed rate of gain for all treatments, and REC steers had similar rates of gain to TRAD and LMI through d 22. Both DM and ME intake was similar for REC, TRAD, and LMI steers through d 22, although from d 8 to 22, TRAD and LMI steers were fed diets with greater percent concentrate. Steers in the REC treatment were moved through the same series of intermediate adaptation diets (72 and 80% concentrate) as TRAD and LMI beginning on d 28. However, REC steers had 28 d compared to 7 d for TRAD and LMI steers to become acclimated to the feedlot and to eating a mixed diet. It is interesting to consider performance of REC vs. TRAD and LMI during the periods when each treatment was moved through the series of transition diets. The relative capacity for REC steers to consume more after 3 weeks in the feedlot is evidenced when DMI was expressed as a percent of BW. During the transition through the 64, 72, and 80% concentrate rations for TRAD and LMI steers, they consumed just over 2% of BW. However, REC steers consumed 2.66% of BW and had almost double

ADG compared to TRAD and LMI while consuming the same series of diets. However, G:F was similar for all treatments from d 23 to 43. Therefore, through 43 d the REC steers had a 29% greater rate of gain (1.46 kg/d) than expected (1.13 kg/d). Because REC steers had an advantage in BW on d 43 the net energy requirements for maintenance and to gain 1.13 kg/d were greater than that of TRAD, LMI, and PF steers. Therefore, increased DMI and ME intake observed in REC steers from d 43 to the end of the growing phase was a result of the program-feeding protocol. Although steers on the ad libitum treatments had feed removed before weighdays, a portion of the BW advantage for REC steers on d 43 may be due to gastrointestinal tract fill. This could also have contributed to the low ADG and efficiencies observed by REC steers during subsequent program-feeding.

The lack of differences in fecal pH and consistency scores, and the absence of clinically observed acidosis between treatments indicate that the frequency and severity of digestive upset was similar among treatments. However, the greater DMI as a percent of BW that REC steers consumed during the time dietary roughage was removed, compared to TRAD and LMI might indicate that TRAD and LMI steers had more digestive upset during dietary adaptation than did REC steers. Had all steers been allowed ad libitum intake of the 88% concentrate diet after adaptation (beginning on d 23 for TRAD, LMI, and PF and d 43 for REC) previous digestive disturbances might have hindered subsequent finishing performance. After summarizing the literature, Brown et al. (2006) suggested adapting cattle to a high-concentrate diet too rapidly (from 55 to 70% to 92 to 95% concentrate in 14 d or less) using incremental increases in concentrate can decrease performance over the entire feeding period. They also noted that even

though bunk management strategies have decreased the day-to-day variations in feed intake for a pen of cattle, greater variation among cattle within pens is likely. This takes into consideration that newly received, high stressed cattle have low feed intake (Hutcheson and Cole, 1986) and visit the feedbunk at varying frequencies and for different lengths of time (Sowell et al., 1999; Buhman et al., 2001). It is possible that the 28 d period REC steers were fed the receiving diet allowed the most vulnerable cattle in that treatment to become completely adapted before energy content was increased in their diets (Bevans et al., 2005).

Fecal Samples

Fecal consistency score (less firm) and decreased pH have been associated with low-forage diets (17 vs. 25% ADF) in lactating dairy cows (Ireland-Perry et al., 1993). Interestingly, more loose feces had a higher DM than did firm. Low-forage diets were also associated with an increase in fecal starch, and fecal pH was negatively correlated with fecal startch ($r = -0.58$). Other studies have correlated fecal pH and starch ($r = -0.94$, Wheeler and Noller, 1977; $r = -0.35$, Russell et al., 1980). Galyean et al. (1977) suggested that this occurs because of increased passage rate in high-concentrate diets, where more starch is available for fermentation in the lower ileum and large intestine; therefore, lowering fecal pH. Xiong et al. (1991) measured fecal pH and starch concentration in steers adapted using a limited maximum intake approach vs. ad libitum transition diets. No effect of feeding regiman was seen in fecal pH or starch. However, they reported an interaction with degree of processing (bulk density of sorghum grain) and fecal starch. Over the entire feeding period, with the exception of d 7 when there

was no difference, fecal starch decreased as flake density decreased indicating processing increased the utilization of dietary starch. Xiong et al. (1991) also showed an increase in fecal starch, with a peak on d 28, along with a decrease in fecal pH as the step-up period progressed followed by a lower plateau in fecal starch and stabilization in fecal pH later during the feeding period. They hypothesized that these responses were due to the low concentration of grain early in the feeding period being digested equally well, regardless of processing, and that the peak was due to lower DMI (as a percent of BW) later in the feeding period, or digestive adaptation. A similar response could explain the tendency for REC steers to have lower fecal pH on d 60 than the other treatments in the present experiment. On d 60, REC steers would only have been consuming the 88% concentrate diet for 17 d, whereas TRAD and LMI and PF steers had been consuming that diet for 37 and 60 d, respectively. In a metabolism experiment, Choat et al. (2002) observed decreased passage rate and improved DM digestibility in steers adapted by limit feeding a high-concentrate diet. They speculated that, despite these improvements in digestibility, low energy intake and a lack of ruminal fill resulted in the decreased performance reported in their performance trials (Exp. 1 and 2). This is possible in the present study, where PF steers consumed the least overall ME and had the lowest overall ADG, although they were among the most efficient utilizers of ME across the experiment..

Finishing Phase and Carcass Characteristics

Due to the large variation in BW among the steers that remained in the finishing phase, combined with fewer replications, initial BW was not different, while final BW after the growing phase was lower for PF steers. Steers in all treatments had greater than

expected ADG and G:F for the first 60 days on feed. This is likely due to a combination of increased gastrointestinal fill in ad libitum fed cattle, and a compensatory response following restricted gain. While LMI did not show any advantage in finishing performance, contrary to Bartle and Preston (1992), steers in the present study were not limited in intake during finishing and would likely have had similar variation in daily DMI as steers on the other three treatments. In the previous experiments mentioned (Xiong et al., 1991; Bartle and Preston, 1992; Bierman and Pritchard, 1996; Weichenthal et al., 1999; Choat et al., 2002) carcass characteristics were generally not different between adaptation treatments. Steers adapted to a high-concentrate diet using limited intake of the finishing diet had greater yield grades and 12th-rib fat thickness (Weichenthal et al., 1999) and tended to have increased marbling scores (Bierman and Pritchard, 1996) compared to those adapted with ad libitum feeding of step-up diets. In the study of Choat et al. (2002), aside from HCW, which resulted from decreased ADG during feeding in Exp. 2, no differences in carcass characteristics were observed. This was similar to the present experiment in which HCW was significantly lower for PF steers than others. Dressing percentage, however, was not different, indicating that lower HCW was reflective of the lower numeric final BW, and was due to decreased gain during the growing phase.

Animal Health

In the reports mentioned previously, incidence of morbidity due to BRD was not reported. With the exception of Exp. 2 in Choat et al. (2002), yearling cattle with lower risk for BRD (Babcock et al., 2009) have been used. The one calf study (Choat et al.,

2002; Exp. 2) used calves that had been preweaned and grazed on wheat pasture prior to feedlot entry, and would similarly have lower risk of developing BRD (Step et al., 2008). Therefore, one of our goals was to obtain cattle with a relatively high risk for BRD and use pens with adequate population numbers to provide a robust indication of the impact of various treatments on the incidence of BRD. Bovine respiratory disease morbidity was relatively high with 38.7% of calves being treated at least once for BRD and mortality of 2.0%.

The reasons for increased morbidity with an increased percent of dietary concentrate are not known (Rivera et al., 2005). While the fecal pH results in the present study and metabolism data in the Choat et al. (2002) study did not detect an increased prevalence of digestive upsets, one postulate is that the higher-concentrate diet results in more cases of sub-clinical ruminal acidosis that are diagnosed incorrectly as BRD. Leedle et al. (1995) monitored health of fistulated cows being adapted to a high-concentrate (90%) diet over 4 weeks. They observed increased rectal temperature of cows after adaptation to 90% concentrate as well as increased respiration rate. This was likely due to increased venous CO_2 as a result of increased ruminal fermentation. A decrease in blood pH was also observed. Adaptation to growing and subsequent finishing diets have been associated with an inflammatory and acute-phase response as well (Ametaj et al., 2009). Therefore, a non-specific inflammatory response due to digestive upset associated with dietary adaptation may cause sickness behavior (Tizard, 2008), and pen riders may misdiagnose these animals with respiratory disease. While not supported by fecal pH or score data in the present experiment, it is possible that TRAD and PF

steers had more incidences of digestive upset and resulted in pulls and treatments of calves that did not actually have respiratory disease.

Increasing concentrate level in receiving diets has long been associated with increased morbidity in calves (Lofgreen et al., 1975). Lofgreen et al. (1975) reported a series of experiments in newly received, lightweight calves shipped long distances from Texas to California and fed receiving diets varied in concentrate level from 20 to 90%. They reported generally increased treatment costs as concentrate level increased from 20 to 72% (Exp. 1), but increased performance by the calves fed 72% concentrate allowed them to regain their purchase weight more quickly. However, when comparing 55, 72 and 90% concentrate rations (Exp. 2), though the 90% concentrate-fed calves had similar weight gain and lower DMI:ADG as the 72% concentrate-fed calves through the receiving period (28 d), Lofgreen et al. (1975) recommended a 72% concentrate ration. Similarly, in the present experiment, the calves fed 88% concentrate initially (PF) or allowed ad libitum adaptation to 88% concentrate during 22 d after arrival had the greatest total morbidity compared to calves fed a 64% concentrate diet for 28 d and those restricted in intake during adaptation from 64 to 88% concentrate (LMI). In the present experiment, PF steers had only 36.4% slick bunks during d 1 to 7, and it appeared that greater than 15% orts were observed on some mornings. Lofgreen et al. (1975) reported calves fed 90% concentrate started on feed slower, as evidenced by lower feed consumption and rate of gain in the first week, and had BRD higher treatment and retreatment rates than those fed 55 or 72% concentrate, similar to the present experiment.

In their review of data from 6 receiving studies conducted at New Mexico State University, Rivera et al. (2005) concluded that decreasing roughage concentration in the

diets of newly received, high-risk calves resulted in slightly higher BRD morbidity rates (1.35% by decreasing roughage 20%). However, improved ADG with higher energy diets overwhelmed the costs of morbidity, and net returns were greater with higher energy diets. Rivera et al. (2005) cautioned that, because of differences in dietary formulation (milled vs. 100% hay diets) and feedstuffs used, results could be confounded by crude protein concentration, and energy density could not be separated from concentrate:roughage ratio. In an attempt to control for those effects Berry et al. (2004a) fed diets with high or low starch (48 or 38% of ME provided by starch) at two energy densities (0.85 or 1.07 Mcal NE_g/kg DM) provided by diets containing 35 or 45% roughage. Performance and overall morbidity were not affected by energy concentration, but morbid calves consuming more energy had lowered shedding of bacterial respiratory pathogens. Additionally, lower starch tended to result in less morbidity. No affects of dietary energy or starch on APP production in that trial were observed (Berry et al., 2004b). Using a lipopolysaccharide challenge model Reuter et al. (2008) observed an increased pro-inflammatory response by calves consuming a low-concentrate (30%) diet ad libitum, followed by a higher-concentrate (70%) diet at the same energy intake, with the least response from calves consuming 70% concentrate ad libitum. In addition, the cytokine IL-4, which regulates the proinflammatory response, was non-detectable pre-challenge in steers on the 30%-concentrate diet. Reuter et al. (2008) suggested that increased morbidity in calves fed higher energy diets was due to less protection by the innate immune system in those calves, and both lower energy and dietary ingredient (more roughage) could enhance the inflammatory protection against disease. However, application of those results to the present experiment are limited as the higher-concentrate

diet in that study was similar to the high-roughage diet fed here. Also of interest, steers on the LMI and PF treatments in the present experiment tended to be detected as being sick an average of 1 to 5 days earlier than TRAD and REC steers. Perhaps a decreased gastrointestinal fill of steers limited in intake altered the perception of personnel seeking visual signs of morbidity and allowed BRD events to be detected earlier.

In summary, feeding a higher-roughage diet for an extended period (28 d) after arrival resulted in the greatest ADG. However, when those cattle subsequently were adapted to a high-concentrate program-fed diet, they were less efficient. A 21-d adaptation period with free access to feed or feeding the high-concentrate diet initially increased the incidence of morbidity from BRD. Therefore, extending the period during which a higher-roughage diet is fed, or limiting the maximum intake during the adaptation period, can decrease morbidity in newly received feedlot steers.

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Table 5.1. Cattle background information.

Lot	Origin	Date[1]			Number	Initial BW, kg	Trial Length, d
		Received	Processing	Trial Initiated			
1	Florida-Texas	11/16 – 11/18/06	11/19/06	11/19/06	184	288 ± 20.2	78
2	Missouri	11/20/06	11/21/06	11/21/06	80	281 ± 20.9	76
3	Missouri-Texas	11/27 – 12/2/06	12/2 – 12/5/06	12/5/06	96	275 ± 10.6	62
4	Missouri-Oklahoma-Texas	11/27 – 12/8/06	12/2 – 12/8/06	12/8/06	176	282 ± 23.8	59

[1]Date steers in the respective loads were received, processed, and allotted, and treatment feeding regimes initiated.

Table 5.2. Composition of experimental diets.

	Growing Phase				Finishing Phase
Percent Concentrate	64	72	80	88	94
Ingredient[1]					
Dry Rolled Corn	43.55	50.45	57.35	64.25	68.50
Corn DDGS	15.70	15.80	15.90	16.00	16.00
Liquid Supplement[2]	1.00	2.00	3.00	4.00	5.00
B-133 Supplement[3]	3.75	3.75	3.75	3.75	-
B-140 Supplement[4]	-	-	-	-	4.50
Ground Alfalfa Hay	18.00	14.00	10.00	6.00	6.00
Ground Prairie Hay	18.00	14.00	10.00	6.00	-
Nutrient composition[1]					
Dry Matter, %	84.06	83.95	86.18	84.54	85.64
ME, mcal/kg	2.66	2.78	2.91	3.05	3.13
NEm, mcal/kg	1.78	1.88	1.97	2.07	2.16
NEg, mcal/kg	1.10	1.18	1.25	1.33	1.42
Crude Protein, %	13.7	11.7	14.3	12.6	14.0
NDF, %	19.1	14.4	13.0	9.2	17.1
ADF, %	34.4	29.1	26.5	20.1	8.7
Calcium, %	0.79	0.70	0.59	0.65	0.55
Phosphorus, %	0.32	0.33	0.34	0.36	0.36

[1]All items except DM on a DM basis. Energy composition calculated (NRC, 1996); other nutrients analyzed (Servi-Tech Laboratories, Dodge City, KS).

[2]Synergy 19-14 (Westway Feed Products, Catoosa, OK).

[3]Meal supplement contained the following (DM basis): 33.33% calcium carbonate, 30.71%, ground corn, 20.00%;soybean meal, 8.00% salt, 4.00% cane molasses, 2.93% magnesium oxide, 0.08% manganous oxide, 0.07% zinc sulfate, 0.09% vitamin A (30,000 IU/g). 0.06% vitamin E (50%), 0.47% Rumensin 80 (Elanco Animal Health, Indianapolis, IN), and 0.26% Tylan 40 (Elanco Animal Health).

[4]Pelleted supplement contained the following (DM basis): 44.44% ground corn, 15.68% wheat middlings, 28.89% limestone, 5.33% salt, 2.22% magnesium oxide, 0.07% manganous oxide, 2.44% potassium chloride, 0.13% zinc sulfate, 0.07% vitamin A (30,000 IU/g), 0.05% vitamin E (50%), 0.42% Rumensin 80 (Elanco Animal Health), and 0.25% Tylan 40 (Elanco Animal Health).

Table 5.3. Schedule of experimental diet and intake regimen for the growing phase, and frequency of slick bunks observed by diet during d 1 to 43.

	Treatment[1]					
Item	TRAD	REC	LMI	PF	SEM[2]	*P* > F[3]
Diet Percent Concentrate[4]						
d 1 to 7	64	64	64	88		
d 8 to 14	72	64	72	88		
d 15 to 22	80	64	80	88		
d 23 to 28	88	64	88	88		
d 29 to 35	88	72	88	88		
d 36 to 43	88	80	88	88		
d 44 to end	88	88	88	88		
Intake Regimen[5]						
d 1 to 7	Ad lib	Ad lib	2.1 MM	Prog		
d 8 to 14	Ad lib	Ad lib	2.3 MM	Prog		
d 15 to 22	Ad lib	Ad lib	2.5 MM	Prog		
d 23 to 28	Prog	Ad lib	Prog	Prog		
d 29 to 35	Prog	Ad lib	Prog	Prog		
d 36 to 43	Prog	Ad lib	Prog	Prog		
d 44 to end	Prog	Prog	Prog	Prog		
Slick Bunks, %[6]						
d 1 – 7	12.3[c]	39.5[b]	61.0[a]	63.6[a]	12.8	<0.001
d 8 -14	30.7[c]	30.7[c]	60.5[b]	90.1[a]	11.4	<0.001
d 15 – 22	57.7[b]	59.6[b]	94.9[a]	93.2[a]	11.1	<0.001
d 23 – 28		80.6				
d 29 – 35		26.2				
d 35 – 43		69.2				

[1]Dietary adaptation program: TRAD = traditional; REC = 28-d ad libitum receiving program;, followed by ad libitum step-up program; LMI = intake of step-up diets limited to 2.1, 2.3, and 2.5 multiples of maintenance energy requirement during weeks 1, 2, and 3, respectively; PF = program-fed a high-concentrate diet to gain 1.13 kg/d.

[2]Standard error of the least squares means (n = 6 pens/treatment).

[3]Probability of the overall F-test.

[4]Percent dietary concentrate of the respective adaptation and growing diets (DM basis).

[5]Intake regimen: Ad lib = ad libitum; 2.1, 2.3, 2.5 MM = multiple of arrival maintenance energy requirement; Prog = program-fed to gain 1.13 kg/d, NE_m and NE_g requirements calculated using NRC (1996) equations. On d 1, TRAD, REC, and LMI steers fed 2.5% of BW of the 64% concentrate diet and PF steers fed equivalent ME of 88% concentrate diet.

[6]Data analyzed as binomially distributed for each pen and day for days 1 to 7, 8 to 14, and 15 to 22. From d 23 to 43, TRAD, LMI, and PF steers had no orts remaining in any

pen on any day. Frequency of slick bunks in REC pens was calculated [number of slick bunks / (number of pens × number of days) × 100].

[abc] Means within a row without a common superscript differ ($P \leq 0.05$).

Table 5.4. Body weight, ADG, DMI, and G:F of steers on four different programs for adaptation to a high-concentrate diet.

	Treatment[1]					
Item	TRAD	REC	LMI	PF	SEM[2]	$P > F$[3]
BW, kg						
d 0	283	282	284	283	6.68	0.55
d 22	306	306	304	302	6.34	0.58
d 43	331[b]	345[a]	330[b]	327[b]	3.70	<0.001
d 59	350[de]	352[d]	347[ef]	345[f]	2.36	0.055
end[5]	359[ab]	363[a]	357[bc]	354[c]	8.16	0.005
ADG, kg/d						
d 1 to 22	1.07	1.09	0.91	0.88	0.154	0.41
d 23 to 43	1.17[b]	1.86[a]	1.28[b]	1.20[b]	0.207	<0.001
d 44 to 59	1.14[a]	0.40[b]	0.97[a]	1.06[a]	0.198	<0.001
d 60 to end[4]	0.96[e]	1.12[d]	1.10[d]	0.95[e]	0.058	0.07
d 1 to 43	1.12[b]	1.46[a]	1.09[b]	1.04[b]	0.077	<0.001
d 44 to	1.09[a]	0.66[b]	1.05[a]	1.01[a]	0.122	0.01
End[5]						
d 1 to end[5]	1.09[b]	1.16[a]	1.05[bc]	1.02[c]	0.031	0.001
DMI, kg/d						
d 1 to 22	5.78[a]	6.05[a]	6.01[a]	4.39[b]	0.275	<0.001
d 23 to 43	6.11[b]	8.68[a]	6.12[b]	6.20[b]	0.218	<0.001
d 44 to 59	6.26[b]	6.47[a]	6.26[b]	6.25[b]	0.055	<0.001
d 60 to end[4]	6.29[b]	6.62[a]	6.29[b]	6.28[b]	0.071	<0.001
d 1 to 43	5.95[b]	7.32[a]	6.07[b]	5.27[c]	0.224	<0.001
d 43 to	6.33[b]	6.54[a]	6.32[b]	6.31[b]	0.402	<0.001
End[5]						
d 1 to end[5]	6.07[b]	6.98[a]	6.13[b]	5.64[c]	0.163	<0.001
DMI, % of BW						
d 1 to 22	1.96[a]	2.05[a]	2.04[a]	1.50[b]	0.087	<0.001
d 23 to 43	1.91[b]	2.66[a]	1.93[b]	1.96[b]	0.056	<0.001
d 44 to 59	1.84	1.86	1.85	1.86	0.027	0.36
d 60 to end[4]	1.74	1.81	1.76	1.77	0.029	0.02
d 1 to 43	1.93[b]	2.33[a]	1.97[b]	1.72[c]	0.069	<0.001
d 43 to end[5]	1.84	1.85	1.85	1.86	0.133	0.31
d 1 to end[5]	1.89[b]	2.15[a]	1.90[b]	1.76[c]	0.052	<0.001
G:F						
d 1 to 22	0.179	0.175	0.151	0.198	0.022	0.15
d 23 to 43	0.191	0.215	0.208	0.193	0.031	0.74
d 44 to 59	0.181[a]	0.061[b]	0.154[a]	0.169[a]	0.030	<0.001
d 60 to end[4]	0.152	0.170	0.175	0.151	0.010	0.12
d 1 to 43	0.189	0.199	0.180	0.196	0.010	0.25
d 43 to end[5]	0.190[a]	0.159[b]	0.187[a]	0.185[a]	0.009	0.057
d 1 to end[5]	0.180[a]	0.167[bc]	0.173[ab]	0.181[a]	0.006	0.01

[1]Dietary adaptation program: TRAD = traditional, ad libitum step-up program; REC = 28-d ad libitum receiving program, followed by ad libitum step-up program; LMI = intake of step-up diets limited to 2.1, 2.3, and 2.5 multiples of maintenance energy requirement during weeks 1, 2, and 3, respectively; PF = program-fed a high-concentrate diet to gain 1.13 kg/d.

[2]Standard error of the Least squares means (n = 6 pens/treatment).

[3]Probability of the overall F-test.

[4]Includes only data from loads 1 and 2 (n=3 pens/treatment).

[5]End BW = the average of weights taken on two consecutive days. Trial length was 78, 76, 62, or 59 days for lots 1, 2, 3, and 4, respectively.

[abc] Means within a row without a common superscript differ ($P \leq 0.05$).

[def] Means within a row without a common superscript differ ($P \leq 0.10$).

Table 5.5. Total dry matter intake (kg/steer) of an individual diet and during days 1 to 59.

	Treatment[1]					
Diet	TRAD	REC	LMI	PF	SEM[2]	$P > F$[3]
64%[4]	33.8[b]	190.0[a]	36.0[b]	-	7.49	<0.001
72%[4]	42.8[b]	65.1[a]	43.7[b]	-	2.34	<0.001
80%[4]	60.1[b]	73.1[a]	59.7[b]	-	2.59	0.003
88%	222.5[b]	93.6[c]	223.0[b]	329.7[a]	2.38	<0.001
Total	358.8[b]	421.5[a]	362.1[b]	330.0[a]	9.40	<0.001

[1]Dietary adaptation program: TRAD = traditional, ad libitum step-up program; REC = 28-d ad libitum receiving program, followed by ad libitum step-up program; LMI = intake of step-up diets limited to 2.1, 2.3, and 2.5 multiples of maintenance energy requirement during weeks 1, 2, and 3, respectively; PF = program-fed a high-concentrate diet to gain 1.13 kg/d.

[2]Standard error of the least squares means (n = 6 pens/treatment).

[3]Probability of the overall F-test.

[4]Includes only data from TRAD, REC, and LMI treatments.

Table 5.6. Metabolizable energy intake and ME efficiency of steers on four different programs for adaptation to a high-concentrate diet.

	Treatment[1]					
Item	TRAD	REC	LMI	PF	SEM[2]	$P > F$[3]
ME Intake, Mcal/d						
d 1 to 22	16.27[a]	16.10[a]	16.85[a]	13.34[b]	0.776	0.002
d 23 to 43	18.49[b]	24.08[a]	18.55[b]	18.81[b]	0.631	<0.001
d 44 to 59	19.01[b]	19.54[a]	18.99[b]	18.97[b]	0.169	0.002
d 60 to end[4]	19.10[b]	20.08[a]	19.10[b]	19.06[b]	0.216	<0.001
d 1 to 43	17.33[bc]	19.97[a]	17.68[b]	16.01[c]	0.625	<0.001
d 43 to end[5]	19.20[b]	19.79[a]	19.18[b]	19.16[b]	1.219	<0.001
d 1 to end[5]	17.96[bcd]	19.75[a]	18.16[b]	17.12[ce]	0.503	<0.001
ADG:ME Intake, g/Mcal						
d 1 to 22	63.91	65.87	53.85	65.17	7.960	0.31
d 23 to 43	63.12	77.56	68.58	63.45	10.313	0.32
d 44 to 59	59.48[a]	20.32[b]	50.85[a]	55.78[a]	10.032	<0.001
d 60 to end[4]	50.18	55.85	57.55	49.87	3.401	0.12
d 1 to 43	63.29[b]	73.50[a]	60.55[b]	61.73[b]	3.358	0.004
d 43 to end[5]	58.58[a]	33.11[b]	56.13[a]	53.99[a]	9.153	0.009
d 1 to end[5]	60.79	58.95	58.27	59.51	2.297	0.38

[1]Dietary adaptation program: TRAD = traditional, ad libitum step-up program; REC = 28-d ad libitum receiving program, followed by ad libitum step-up program; LMI = intake of step-up diets limited to 2.1, 2.3, and 2.5 multiples of maintenance energy requirement during weeks 1, 2, and 3, respectively; PF = program-fed a high-concentrate diet to gain 1.13 kg/d.
[2]Standard error of the least squares means (n = 6 pens/treatment).
[3]Probability of the overall F-test.
[4]Includes only data from loads 1 and 2 (n=3 pens/treatment).
[5]End BW = the average of weights taken on two consecutive days. Trial length was 78, 76, 62, or 59 days for lots 1, 2, 3, and 4, respectively.
[abc] Means within a row without a common superscript differ ($P \leq 0.05$).
[def] Means within a row without a common superscript differ ($P \leq 0.10$).

Table 5.7. Morbidity, mortality, and days on feed to treatment of steers adapted to a high-concentrate diet using four methods.

	Treatment[1]						Odds Ratios vs. TRAD[2]		
Item	TRAD	REC	LMI	PF	SEM[3]	$P > F$[4]	REC	LMI	PROG
Morbidity, %[5]									
Total	42.16[d]	33.13[de]	30.13[e]	42.91[d]	5.45	0.08	0.68	0.59	1.03
Retreat	19.30	15.56	19.51	29.31	6.19	0.59	0.77	1.01	1.73
Treated once	34.24	28.28	24.55	30.51	4.33	0.34	0.76	0.63	0.84
Treated twice	5.20	3.73	3.73	5.20	1.93	0.87	0.70	0.70	1.00
Treated thrice	2.95[de]	1.48[e]	2.21[e]	7.39[d]	2.47	0.07	0.49	0.74	2.62
Mortality, %[6]									
Dead	4.48	0.74	1.49	0.75	1.05	0.48	0.16	0.32	0.16
CFR	8.07	2.18	0.00	1.70	3.46	0.40	0.25	0.00	0.20
Days on feed[7]									
First treatment	11.0[de]	13.0[d]	7.3[f]	9.4[ef]	2.07	0.09			
Second treatment	18.9	25.7	14.3	18.5	4.94	0.38			
Third treatment	27.8	16.0	25.7	27.4	9.51	0.76			

[1]Dietary adaptation program: TRAD = traditional, ad libitum step-up program; REC = 28-d ad libitum receiving program, followed by ad libitum step-up program; LMI = intake of step-up diets limited to 2.1, 2.3, and 2.5 multiples of maintenance energy requirement during weeks 1, 2, and 3, respectively; PF = program-fed a high-concentrate diet to gain 1.13 kg/d.

[2]Odds ratios of REC, LMI, and PF compared to TRAD.

[3]Standard error of the Least squares means (n = 6 pens/treatment).

[4]Probability of the overall F-test.

[5]Bovine respiratory disease morbidity: Total = number treated at least once for BRD; Retreat = number treated 2 or more times as a percent of those treated at least once; Treated once, twice, or thrice = the number treated that received 1, 2, or 3 total antimicrobial treatments.

[6]Mortality: Total = number of mortalities as a percent of the total number enrolled in the study; CFR, case fatality rate = the number of dead animals that had received antimicrobial treatment for BRD as a percent of those that received at least one antimicrobial treatment for BRD.

[7]Average days on feed at the time of first, second, or third antimicrobial treatment for BRD.

[abc] Means within a row without a common superscript differ ($P \leq 0.05$).

[def] Means within a row without a common superscript differ ($P \leq 0.10$).

Table 5.8. Finishing phase performance of steers adapted to a high-concentrate diet using four methods during the growing phase.

	Treatment[1]					
Item	TRAD	REC	LMI	PF	SEM[2]	$P > F$[3]
BW, kg						
d 0	346	361	335	337	35.26	0.27
d 60	475[de]	491[d]	476[de]	460[e]	38.72	0.08
Final[4]	585	598	582	565	19.46	0.15
Carc. Adj.[5]	585[a]	601[a]	581[ab]	563[b]	18.95	0.04
ADG, kg/d						
d 0 to 60	2.17	2.20	2.38	2.08	0.131	0.25
d 60 to end[4]	1.32	1.43	1.16	1.38	0.180	0.74
d 0 to end[4]	1.70	1.78	1.73	1.70	0.157	0.94
Adj. 0 to end[45]	1.69	1.81	1.72	1.69	0.150	0.80
DMI, kg/d						
d 0 to 60	9.08	9.33	9.39	8.78	0.772	0.45
d 60 to end[4]	10.67	10.99	10.46	10.15	0.524	0.54
d 0 to end[4]	9.82	10.27	10.03	9.59	0.548	0.56
DMI, % of BW[6]						
d 0 to 60	2.22	2.19	2.32	2.20	0.051	0.35
d 60 to end[4]	1.96	2.02	1.98	1.98	0.064	0.92
d 0 to end[4]	2.11	2.14	2.19	2.12	0.051	0.72
G:F						
d 0 to 60	0.240	0.237	0.256	0.241	0.018	0.82
d 60 to end[4]	0.125	0.130	0.110	0.136	0.014	0.60
d 0 to end[4]	0.171	0.173	0.172	0.178	0.009	0.95
Adj. 0 to end[45]	0.171	0.176	0.171	0.176	0.008	0.89

[1]Dietary adaptation program: TRAD = traditional, ad libitum step-up program; REC = 28-d ad libitum receiving program, followed by ad libitum step-up program; LMI = intake of step-up diets limited to 2.1, 2.3, and 2.5 multiples of maintenance energy requirement during weeks 1, 2, and 3, respectively; PF = program-fed a high-concentrate diet to gain 1.13 kg/d.

[2]Standard error of the Least squares means (n = 3 pens/treatment).

[3]Probability of the overall F-test.

[4]Final BW, 104, 134, 167 days on feed for blocks 1, 2, and 3, respectively.

[5]Carcass adjusted final BW calculated by dividing HCW by average dressing percent for each block (63.79, 62.91, and 64.13% for blocks 1, 2, and 3, respectively).

[6]Dry matter intake expressed as a percent of average BW for each period.

[abc] Means within a row without a common superscript differ ($P \leq 0.05$).

Table 5.9. Carcass characteristics of steers adapted to a high-concentrate diet using four methods during the growing phase[1].

	Treatment[2]					
Item	TRAD	REC	LMI	PF	S.E.M.[3]	$P > F$[4]
HCW, kg	372[ab]	382[a]	369[ab]	358[bc]	11.79	0.04
Dress, %	63.7	63.9	63.5	63.3	0.54	0.81
FT, cm	1.15	1.29	1.22	1.02	0.115	0.26
LM area, cm^2	84.42	84.26	81.51	80.84	2.011	0.27
Internal fat, %	2.21	2.28	2.19	2.20	0.119	0.66
Yield Grade	2.98	3.28	3.14	2.97	0.149	0.22
Marbling score	362	407	396	391	2.27	0.22

[1]Finishing phase days on feed = 104, 134, and 167 for blocks 1, 2, and 3, respectively.
[2]Dietary adaptation program: TRAD = traditional, ad libitum step-up program; REC = 28-d ad libitum receiving program, followed by ad libitum step-up program; LMI = intake of step-up diets limited to 2.1, 2.3, and 2.5 multiples of maintenance energy requirement during weeks 1, 2, and 3, respectively; PF = program-fed a high-concentrate diet to gain 1.13 kg/d.
[3]Standard error of the least squares means (n = 3 pens/treatment).
[4]Probability of the overall F-test.
[8]300 = slight 0, 400 = small 0; 500 = modest 0.
[abc] Means within a row without a common superscript differ ($P \leq 0.05$).

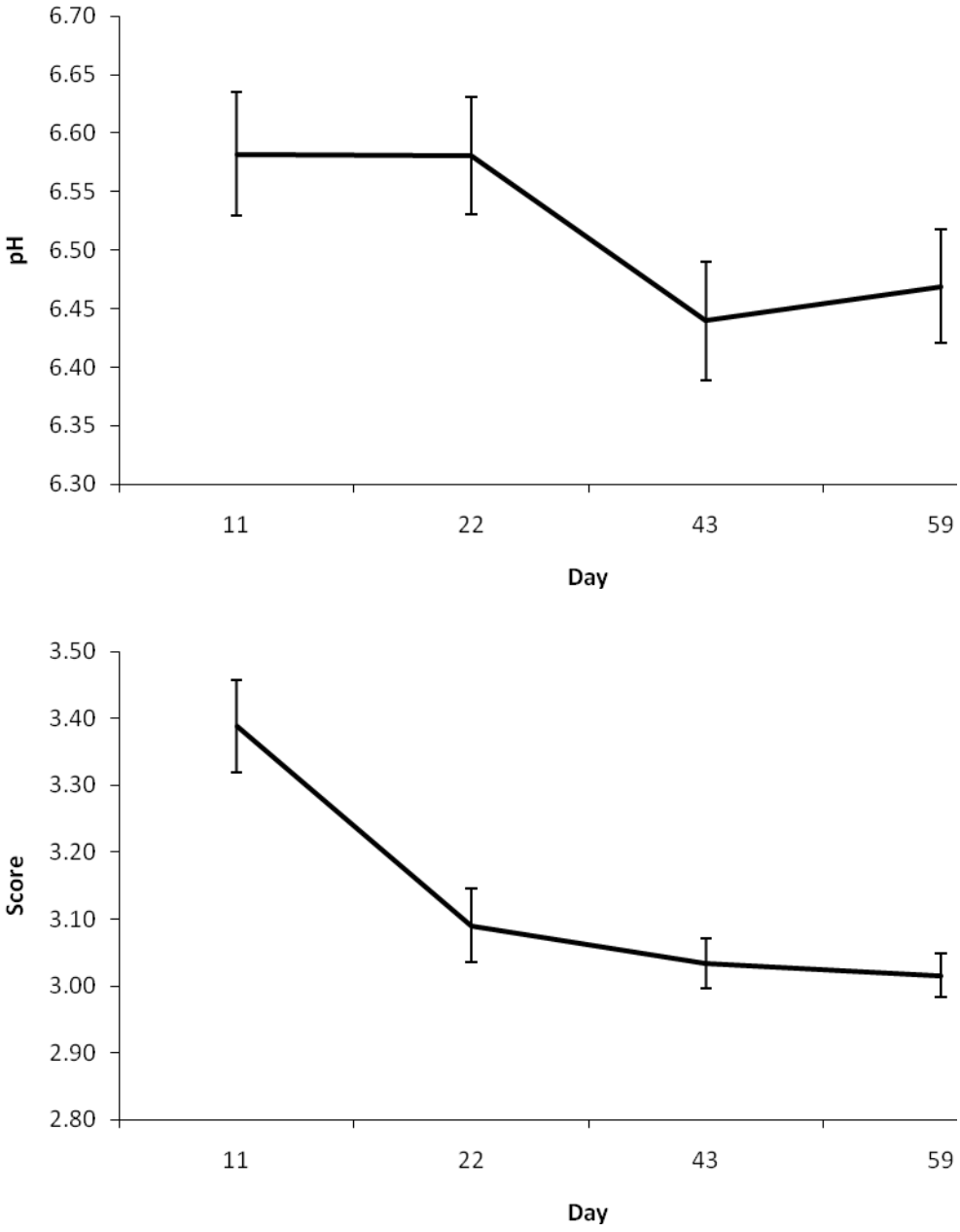

Figure 5.1. Fecal pH and consistency score of steers adapted to a high-concentrate, program-fed diet using four methods. For both fecal pH, there was a tendency for a treatment × day interaction ($P = 0.06$) where REC steers tended to have lower fecal pH at d 60 than the other three treatments. Across, days pH decreased ($P = 0.001$; treatment, $P = 0.85$). Fecal score decreased over time ($P < 0.001$; treatment, $P = 0.98$; treatment × day, $P = 0.21$). The lines represent least squares means for day ± S.E.M. (n = 36 steers/treatment).

APPENDIX

All procedures involving live animals were approved by the

Oklahoma State University Institutional Animal Care and Use Committee.

Oklahoma State University Institutional Review Board

Date: Friday, June 01, 2007
IRB Application No: AG0722
Proposal Title: Cattle Health Monitoring System Validation

Reviewed and Processed as: Exempt

Status Recommended by Reviewer(s): Approved Protocol Expires: 5/31/2008

Principal Investigator(s):

Deborah VanOverbeke
104D An. Sci.
Stillwater, OK 74078

Ben Holland
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Stillwater, OK 74078

The IRB application referenced above has been approved. It is the judgment of the reviewers that the rights and welfare of individuals who may be asked to participate in this study will be respected, and that the research will be conducted in a manner consistent with the IRB requirements as outlined in section 45 CFR 46.

☑ The final versions of any printed recruitment, consent and assent documents bearing the IRB approval stamp are attached to this letter. These are the versions that must be used during the study.

As Principal Investigator, it is your responsibility to do the following:

1. Conduct this study exactly as it has been approved. Any modifications to the research protocol must be submitted with the appropriate signatures for IRB approval.
2. Submit a request for continuation if the study extends beyond the approval period of one calendar year. This continuation must receive IRB review and approval before the research can continue.
3. Report any adverse events to the IRB Chair promptly. Adverse events are those which are unanticipated and impact the subjects during the course of this research; and
4. Notify the IRB office in writing when your research project is complete.

Please note that approved protocols are subject to monitoring by the IRB and that the IRB office has the authority to inspect research records associated with this protocol at any time. If you have questions about the IRB procedures or need any assistance from the Board, please contact Beth McTernan in 219 Cordell North (phone: 405-744-5700, beth.mcternan@okstate.edu).

Sincerely,

Shelia Kennison, Chair
Institutional Review Board

VITA

Ben Patrick Holland

Candidate for the Degree of

Doctor of Philosophy

Dissertation: MANAGEMENT OF NEWLY RECEIVED FEEDLOT CATTLE AND THE EFFECTS OF BOVINE RESPIRATORY DISEASE ON FEEDLOT PERFORMANCE AND CARCASS ATTRIBUTES

Major Field: Animal Nutrition

Biographical:

Personal Data: Born in Dumas, Texas, on September 11, 1981, the son of John and Gail Holland.

Education: Graduated from Texline High School, Texline, Texas in May 2000; received Bachelor of Science in Animal Science with a minor in chemistry from Texas Tech University, Lubbock, Texas in May 2004; received the Master of Science degree with a major in Animal Science at Oklahoma State University in July 2006; and completed the requirements for the Doctor of Philosophy degree in Animal Nutrition at Oklahoma State University in July 2009.

Experience: Employed as a summer laborer by Mac Kehoe Cattle, Texline, Texas, 1995 to 2004; Department of Animal Science, Texas Tech University, Lubbock, Texas as an undergraduate research assistant, 2000 to 2002; served as Texas Tech Masked Rider, 2003-2004, Texas Tech University; graduate research assistant, 2004-present, and research coordinator, Willard Sparks Beef Research Center, 2005 to 2009, Department of Animal Science, Oklahoma State University.

Professional Memberships: American Society of Animal Science; American Registry of Professional Animal Scientists; Gamma Sigma Delta

Name: Ben Patrick Holland Date of Degree: July, 2009

Institution: Oklahoma State University Location: Stillwater, Oklahoma

Title of Study: MANAGEMENT OF NEWLY RECEIVED FEEDLOT CATTLE AND THE EFFECTS OF BOVINE RESPIRATORY DISEASE ON FEEDLOT PERFORMANCE AND CARCASS ATTRIBUTES

Pages in Study: 181 Candidate for the Degree of Doctor of Philosophy

The effects of serum haptoglobin (Hp) concentration on growing phase performance and Bovine Respiratory Disease (BRD) morbidity and mortality was evaluated using 337 heifer calves (initial BW = 241.3). Heifers were allocated into pens according to serum Hp concentration measured on arrival and classified as LOW (< 1.0 µg/100 mL), MED (1 to 3 µg/100 mL) or HIGH (> 3.0 µg/100 mL). Across the entire 63-d growing phase, ADG and DMI were similar among Hp treatment groups, but ADG and DMI were lowest for HIGH heifers during the first 7 and 21 days, respectively. Overall morbidity and the number of heifers requiring 3 treatments were greater for MED and HIGH than LOW. Following the growing phase, 193 heifers were selected for a finishing experiment in which they were classified into pens based on the number of BRD treatments they received during the growing phase. Heifers were never treated for BRD (0X), treated 1 time (1X), 2 times (2X), 3 times (3X), or were considered chronically ill (C). Disease incidence decreased ADG during the growing phase so that initial BW for the finishing phase was linearly decreased as the number of BRD treatments increased. During finishing, a compensatory response was observed in treated heifers so that final BW and carcass characteristics for those were similar to healthy heifers. However, an additional 18 days on feed was required for 3X heifers to produce those carcasses. Retail shelf life, tenderness, and palatability attributes were not different between BRD treatment groups. A third experiment used 536 steers (initial BW = 284.4 kg) to evaluate four methods of adaptation to a high-concentrate diet during a 60-d growing period. Experimental treatments were: 1) a traditional program in which three diets with an increasing percentage of concentrate from 65% to 80% were fed ad libitum during the first 21 d prior to feeding an 88% concentrate diet; 2) ad libitum feeding of the same 65% concentrate diet as in TRAD for the first 28 d, followed by adaptation to and feeding of the 88% concentrate diet; 3) the step-up diets of treatment 1 were used, except maximum feed intake was limited to 2.1, 2.3, and 2.5 times the arrival maintenance energy requirement for weeks 1, 2, and 3, respectively; and 4) program-feeding of the 88% concentrate diet from d 1. Limiting maximum intake of steers, or extending the period during which a higher-roughage diet is fed during dietary adaptation can decrease BRD morbidity. Efficiency of subsequent program-fed gain is decreased for steers fed on an extended ad libitum adaptation program during the growing phase.

ADVISER'S APPROVAL: Clinton R. Krehbiel