REMOTE RUMINAL TEMPERATURE MONITORING IN FEEDLOT CATTLE: EFFECTS OF BOVINE RESPIRATORY DISEASE, RUMINAL ACIDOSIS, AND INCLUSION OF DIETARY β-ADRENERGIC AGONISTS

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TABLE OF CONTENTS

Chapter Page

Chapter Page

Chapter Page

LIST OF TABLES

Table Page

Table Page

LIST OF FIGURES

Figure Page

Figure Page

Figure Page

ABBREVIATIONS

ADF	Acid detergent fiber
ADG	Average daily gain
βAA	Beta-adrenergic agonists
BAL	Bronchoalveolar lavage
BHV-1	Bovine herpesvirus type 1
BRD	Bovine respiratory disease
BRSV	Bovine respiratory syncytial virus
BVDV	Bovine viral diarrhea virus
BW	Bodyweight
CP	Crude protein
DM	Dry matter
DMI	Dry matter intake
G:F	Gain:Feed
HCW	Hot carcass weight
IBR	Infectious bovine rhinotracheitis virus
KPH	Kidney, pelvic, and heart fat
LM	Longissimus muscle
MARC	Meat Animal Research Center

MGA	Melengestrol acetate
NDF	Neutral detergent fiber
NE_g	Net energy for gain
NE_m	Net energy for maintenance
OADDL	Oklahoma Animal Disease Diagnostic Laboratory
PI-BVDV	Persistent infection with bovine viral diarrhea virus
PI_3V	Parainfluenza type 3 virus
RecT	Rectal temperature
RumT	Ruminal temperature
SEM	Standard error of the mean
THI	Temperature-humidity index
VFA	Volatile fatty acids
WSBRC	Willard Sparks Beef Research Center
ZH	Zilpaterol-HCl

CHAPTER I

INTRODUCTION

Body temperature has long been used as a method of evaluating health status of livestock. The normal body temperature of cattle during periods of thermoneutrality ranges from 38.2°C for non-pregnant cows to 38.7°C for young calves (Wrenn et al., 1961). Body temperatures exhibit diurnal variations, with ranges of 0.7°C and 0.6°C for cows and calves, respectively, with maximum temperatures generally occurring during the early afternoon (Wrenn et al., 1961). Body temperatures, however, can be highly variable. Hahn et al. (1990) indicated that temperatures of feedlot cattle may fluctuate by as much as 1.2°C during the day, with maximum temperatures occurring as late as midnight. Normal body temperatures depend on a number of variables, including both animal and environmental factors. Therefore, normal body temperatures must be determined on an individual herd basis.

There are many factors that influence body temperature of cattle. Cattle suffering from illness frequently exhibit elevated body temperatures, with 39.7°C indicating a need for treatment (Duff and Galyean, 2007); however, rectal temperatures of 40.0°C are more commonly used as a lower threshold of fever (Step et al., 2008). The type of diet fed may affect body temperatures. Diets containing highly-fermentable feeds increase the heat of fermentation in the rumen, resulting in a greater heat load for the animal.

Body temperatures will generally increase during hot environmental conditions, although this response is oftentimes breed-dependent. Body temperatures of heat-tolerant breeds will not be largely affected by hot environmental temperatures (Olbrich et al., 1972). Additionally, in colder environments, body temperatures are similar between breeds adapted to hot and cold conditions; however, heat-tolerant breeds exhibit lower body temperatures than cold-tolerant breeds when exposed to hot environments (Olbrich et al., 1972).

METHODS OF MONITORING BODY TEMPERATURE

Many methods of remotely monitoring body temperature have been explored in cattle, including tympanic, vaginal, ruminal or reticular temperatures, as well as implanting subdermal temperature monitors. Employing the use of remote temperature monitors provides many benefits compared to traditional one-time rectal temperature measurements. Remote monitoring enables herd managers to track cattle temperatures without handling the animals. Cattle that are handled frequently may exhibit increased temperatures as a result of the stress of handling (Dracy et al., 1963). Additionally, cattle that must walk long distances from their pen to the handling facilities may exhibit elevated temperatures (Mader et al., 2005).

Remote temperature monitoring may also be beneficial by continuously recording temperatures throughout the day (Hicks et al., 2001). Complete daily temperature data provides a more useful measure of body temperature compared to a single point-in-time observation. Measurements such as maximum daily temperature, average daily temperature, and range of daily temperature may all be used to assess thermal status of cattle.

The feasibility of each of these methods is dependent upon the stage of animal production, and the reliability of the device. For example, rectal and vaginal temperature monitors must be checked frequently, as unclean probes in the rectum or vagina may lead to infection (Brown-Brandl et al., 2003; Hicks et al., 2001). Ear infections may also become a problem with tympanic temperature monitors, and these types of devices should be rotated between ears every 7 to 10 d (Brown-Brandl et al., 2003). Additionally, vaginal temperature monitors may be feasible for use in a dairy, but not for feedlots, where a high percentage of cattle are steers.

Subdermal Temperature

Several studies have been conducted that continuously measure body temperature using surgically implanted devices (Lefcourt et al., 1986; Simmons et al., 1965). These devices are placed under the skin near the abdominal region, and remain with the animal for the duration of its life, or until surgically removed. These devices have been effective at detecting intramammary infection in dairy cows (Lefcourt et al., 1986) and heat stress in feedlot cattle (Lefcourt and Adams., 1996). This type of system has limitations in practical situations due to the cost, time, and labor associated with surgically implanting each animal in a herd. Ideal remote temperature monitoring systems should be reliable, inexpensive, and simple to implement. This type of system would be best suited for use in high-risk animals within a population, rather than in an entire herd of cattle.

Tympanic Temperature

The use of tympanic temperature monitoring systems is best suited for short-term monitoring situations, as temperature probes must be frequently maintained (Brown-Brandl et al., 2003). Hahn et al. (1990) demonstrated that tympanic temperatures are closely correlated to rectal temperatures, concluding that tympanic temperatures are an effective measure of body temperature in cattle. However, tympanic temperatures are more variable than rectal temperatures, likely the result of decreased response time to both internal and environmental factors (Hahn et al., 1990). Therefore, a series of tympanic temperatures are more meaningful than a single temperature time point. Since this system is best used in short-term situations, tympanic temperature monitoring may provide most optimal use during times of the year when heat stress or illness concerns are greatest.

Ruminal Temperature

The use of intra-ruminal temperature monitoring devices has been explored for more than 40 years (Dracy et al., 1963). These battery-operated devices are designed to rest at the bottom of the reticulum. The weight and size of the device prevent passage through the digestive tract. Therefore, these devices will remain in the reticulum for the life of the animal.

Ruminal temperatures have been effectively used to predict rectal temperatures in cattle (Sievers et al., 2004). Bewley et al. (2008a) concluded that reticular temperatures of dairy cows are highly correlated to rectal temperatures, indicating that reticular temperature has usable applications as a method of predicting rectal temperature. However, reticular temperatures observed by Bewley et al. (2008a) were more variable than rectal temperatures.

Other factors influencing reticular temperature included season, stage of lactation, housing, and parity.

The main drawback of ruminal temperature monitoring devices is the marked decline in temperature associated with water consumption. The amount of water consumed and the temperature of the water both affect the magnitude and duration of rumen temperature changes (Brod et al., 1982). Bewley et al. (2008b) observed that rumen temperature declined 8.5°, 6.9°, and 2.2°C when cows consumed 25.2 kg of cold (7.6°C), warm (18.2°C), or hot (34.3°C) water, respectively. Dracy et al. (1963) measured changes in ruminal temperatures of sheep after water consumption. After consuming 0.68 kg of 5°C water, temperatures did not rise to pre-consumption levels for 85 minutes. Additionally, after consuming 1.23 kg of 22.5°C water, temperatures rose to pre-consumption levels after 79 minutes. Temperatures required 55 minutes to return to baseline levels after consuming 0.68 kg of 22°C water, and 90 minutes when 1.36 kg of 22°C water was consumed. This indicates that ruminal temperatures are greatly affected not only by the amount of water consumed, but the temperature of the water as well. When utilizing ruminal temperatures as a method of monitoring body temperature, water drinking events must therefore be considered.

INFLUENCE OF HEALTH STATUS ON BODY TEMPERATURE

Newly received feedlot cattle are highly susceptible to disease. The stress of weaning, transportation, and commingling with new pen mates decreases immune function, while exposure to dust, various pathogens, and new environmental conditions increase the likelihood of disease transfer (Step et al., 2008).

Prior to shipping, body temperature may be used as an indicator of stress in weaned stocker calves moving through auction markets (Thrift et al., 1994). Furthermore, Thrift et al. (1994) noted that cattle sired by British breeds were more likely to have elevated temperatures than those sired by Continental breeds, bulls were more likely to have elevated temperatures compared to steers, and calves with a low degree of coat shedding were more likely to have elevated temperatures compared to those that were classified as "slick-shed." While temperature may indicate the degree of stress, it is expensive and impractical for stocker producers to treat calves for disease at auction markets, as the benefits of antimicrobial treatments are not observed until after exchange of ownership. Unfortunately, as a result, feedlot operators oftentimes are faced with the burden of combating disease in these newly received calves (Thrift et al., 1994).

Bovine respiratory disease (**BRD**) is the most common illness observed in newly received feedlot calves, and has the greatest economic impact of any other disease observed in the feedlot industry (Snowder et al., 2006). Cattle affected by BRD returned $40.64, $58.35, and $291.93 less when treated once, twice, or three or more times, respectively, compared to healthy calves (Fulton et al., 2002). Therefore, management of BRD is of great economic importance to cattle feeders.

Cattle suffering from BRD may exhibit fevers between 40.0° to 42.2°C (Currin and Whittier, 2000). Rectal temperatures should be obtained in the morning from cattle that are suspected to be ill, as greater environmental temperatures during the afternoon may falsely increase the animal's true body temperature (Currin and Whittier, 2000). Rose-Dye et al (2011) challenged steers with bovine viral diarrhea virus or *Mannheimia haemolytica* or both

and observed that maximum ruminal temperatures increased by 1.1°C in response to challenge compared to control.

INFLUENCE OF DIET ON BODY TEMPERATURE

Body temperatures of cattle may be slightly, yet measurably, influenced by diet. Most simply, the amount of feed cattle consume may affect body temperatures. Greater intake levels are associated with greater production of metabolic heat, resulting in increased body temperatures. Cattle exhibit greater rectal temperatures when offered feed at high intake levels compared to cattle that are limit-fed (Reynolds et al., 1991). Mader et al. (1999) demonstrated that during times of hot environmental conditions, restricting intake to 90% of ad libitum levels reduces body temperature of feedlot steers by as much as 1°C compared to cattle offered feed ad libitum.

Highly fermentable feedstuffs, such as processed grains, are common in feedlot diets. These types of diets will cause an increase in the heat of fermentation as a result of a shift in the microbial population of the rumen. High-grain diets are associated with lower ruminal pH, as bacteria that ferment soluble carbohydrates also produce high amounts of lactic acid (pKa=3.86) as a product of fermentation (Dehority, 2003). When not managed and monitored properly, cattle on high-grain diets are in danger of experiencing ruminal acidosis. AlZahal et al. (2008) observed that ruminal temperatures of Holstein cows increased as pH declined when feeding a highly fermentable diet, concluding that ruminal temperature may be used as an indicator of ruminal acidosis.

Mader et al. (1999) measured the effects of dietary roughage level on body temperature in feedlot cattle. Over three periods, cattle were offered diets containing 40%,

25%, and 10% roughage. For each 15% reduction in forage content, rectal temperatures increased by about 0.5°C. This effect was enhanced when cattle were housed in hot conditions compared to thermoneutral conditions.

The use of β-adrenergic agonists (**βAA**) has been shown to be an effective method of increasing hot carcass weight and dressing percentage, and decreasing yield grade, without affecting meat quality (Moloney et al., 1990, Quirke et al., 1988). A number of βAA have been used in feedlot diets, including clenbuterol, ractopamine hydrochloride, and zilpaterol hydrochloride.

When absorbed, βAA behave similarly to catecholamines, and biological responses include increases in respiration and heart rates, with the latter resulting in greater blood flow to the hindquarter (Eisemann et al., 1988). Protein retention increases, and fat mobilization increases, resulting in a greater red meat yield (Eisemann et al., 1988). The effect of βAA on body temperature has not been explored extensively in livestock animals. However, some studies have investigated the effect of βAA on body temperature of other species. Body temperature of rats was not affected by administration of the βAA BRL37344 or the β-adrenergic antagonist SR59230A (Gasparetti et al., 2005). Body temperature of mice was also not affected when orally administered clenbuterol or ractopamine hydrochloride (Page et al., 2004).

Chwalibog et al. (1996) measured heat production in bull calves offered 0, 5, 10, or 20 mg L-644,969/d, and discovered that calves consuming βAA exhibited greater heat production than control calves. Furthermore, the amount of heat produced as a result of protein and carbohydrate fermentation was lower in treated calves compared to control, while the heat of fat fermentation was greater for calves offered βAA.

It should be noted that increased heat production does not equate to increased body temperatures. Cattle that are adapted to and living in cold environments have been shown to produce 32% more heat compared to cattle adapted to and living in hot environments (Robinson et al., 1986). However, rectal temperatures of cattle housed in cold environments are 1.4°C less than that of cattle in hot conditions (Robinson et al., 1986).

SUMMARY

Cattle are extraordinarily capable of maintaining a narrow range of body temperatures. However, even within this narrow range, there is a great amount of variability across breeds, sex, physiological state, diet, and environmental conditions. Continually measuring body temperatures provides valuable information with respect to influences of health and diet.

While all systems of remote temperature monitoring have advantages, none of them provide long-term, minimally invasive methods of measuring true body temperatures. Tympanic temperature reading devices are better suited for short-term use. Subdermal devices require invasive surgeries, and temperatures obtained from ruminal devices are greatly affected by water consumption. Herd managers must weigh the benefits and limitations associated with each of these systems to determine the most appropriate method of temperature monitoring for their operation. The following chapters discuss effects of illness and diet on ruminal temperature of feedlot cattle. This type of remote temperature monitoring was selected as it is permanent and minimally invasive, and it involved a one-time bolus administration. The effect of water consumption on ruminal temperatures were appropriately considered in each of the following chapters.

LITERATURE CITED

AlZahal, O., E. Kebreab, J. France, M. Froetschel, and B. W. McBride. 2009. Ruminal temperature may aid in the detection of subacute ruminal acidosis. J. Dairy Sci. 91:202-207.

Bewley, J. M., M. E. Einstein, M. W. Grott, and M. M. Schutz. 2008a. Comparison of reticular and rectal core body temperatures in lactating dairy cows. J. Dairy Sci. 91:4661-4672.

Bewley, J. M., M. W. Grott, M. E. Einstein, and M. M. Schutz. 2008b. Impact of intake water temperatures on reticular temperatures of lactating dairy cows. J. Dairy Sci. 91:3880-3887.

Brod, D. L., K. K. Bolsen, and B. E. Brent. 1982. Effect of water temperature in rumen temperature, digestion, and rumen fermentation in sheep. J. Anim. Sci. 54:179-182.

Brown-Brandl, T. M., T. Yanagi, Jr., H. Xin, R. S. Gates, R. A. Bucklin, and G. S. Ross. 2003. A new telemetry system for measuring core body temperature in livestock and poultry. Appl. Eng. Agric. 19:583-589.

Chwalibog, A., K. Jensen, and G. Thorbek. 1996. Oxidation of nutrients in bull calves treated with β-adrenergic agonists. Arch. Anim. Nutr. 49:255-261.

Currin, J. F., and W. D. Whittier. 2000. Recognition and treatment of bovine respiratory disease complex. Virginia Cooperative Extension: 400-008. Accessed April 1, 2009 at http://www.ext.vt.edu/pubs/beef/400-008/400-008.html.

Dehority, B. A. 2003. Rumen Microbiology. 1st ed. Nottingham Univ. Press, Nottingham, UK.

Dracy, A. E., W. O. Essler, and J. R. Jahn. 1963. Recording intrareticular temperatures by radiosonde equipment. J. Dairy Sci. 43:241-242.

Duff, G. C., and M. L. Galyean. 2007. BOARD-INVITED REVIEW: Recent advances in management of highly stressed, newly received feedlot cattle. J. Anim. Sci. 85:823-840.

Eisemann, J. H., G. B. Huntington, and C. L. Ferrell. Effects of dietary clenbuterol on metabolism of the hindquarters in steers. J. Anim. Sci. 66:342-353.

Fulton, R. W., B. J. Cook, D. L. Step, A. W. Confer, J. T. Saliki, M. E. Payton, L. J. Burge, R. D. Welsh, and K. S. Blood. 2002. Evaluation of health status of calves and the impact on feedlot performance: Assessment of a retained ownership program for postweaning calves. Can. J. Vet. Res. 66:173-180.

Gasparetti, A. L., F. Alvarez-Rojas, E. P. de Araujo, A. E. Hirata, M. J. A. Saad, and L. A. Velloso. 2005. β3-Adrenergic-dependent and -independent mechanisms participate in cold-induced modulation of insulin signal transduction in brown adipose tissue of rats. Eur. J. Physiol. 449:537-546.

Hahn, G. L., R. A. Eigenberg, J. A. Nienaber, and E. T. Littledike. 1990. Measuring physiological responses of animals to environmental stressors using a microcomputer-based portable datalogger. J. Anim. Sci. 68:2658-2665.

Hicks, L. C., W. S. Hicks, R. A. Bucklin, J. K. Shearer, D. R. Bray, P. Soto, and V. Carvalho. 2001. Comparison of methods of measuring deep body temperatures of dairy cows. Pages 432-438 in Livestock Environment VI: Proceedings of the 6th Int. Symp. ASAE, Louisville, KY. Am. Soc. Agric. Biol. Eng., St. Joseph, MI.

Lefcourt, A. M., and W. R. Adams. 1996. Radiotelemetry measurement of body temperatures of feedlot steers during summer. J. Anim. Sci. 74:2633-2640.

Lefcourt, A. M., J. Bitman, D. L. Wood, and B. Stroud. 1986. Radiotelemetry system for continuously monitoring temperature in cows. J. Dairy Sci. 69:237-242.

Mader, T. L., M. S. Davis, and W. M. Kreikemeier. 2005. Case study: Tympanic temperature and behavior associated with moving feedlot cattle. Prof. Anim. Sci. 21:339-344.

Mader, T. L., J. M. Caughan, and B. A. Young. 1999. Feedlot diet roughage level of Hereford cattle exposed to excessive heat load. Prof. Anim. Sci. 15:53-62.

Moloney, A. P., P. Allen, D. B. Ross, G. Olson and E. M. Convey. 1990. Growth, feed efficiency, and carcass composition of finishing Friesian steers fed the beta-adrenergic agonist L-644,969. J. Anim. Sci. 68:1269-1277.

Olbrich, S. E., F. A. Martz, H. D. Johnson, S. W. Phillips, A. C. Lippincott and E. S. Hilderbrand. 1972. Effect of Constant Ambient Temperatures of 10 C and 31 C on Ruminal Responses of Cold Tolerant and Heat Tolerant Cattle. J. Anim. Sci. 34:64-69.

Page, K. A., D. L. Hartzell, C. Li, A. L. Westby, M. A. Della-Fera, M. J. Azain, T. D. Pringle, and C. A. Baile. 2004. B-Adrenergic receptor agonists increase apoptosis of adipose tissue in mice. Domest. Anim. Endocrinol. 24:23-31.

Quirke, J. F., P. Allen, A. P. Moloney, M. Sommer, J. P. Hanrahan, W. Sheehan, and J. F. Roche. 1988. Effects of the beta-agonist cimaterol on blood metabolite and hormone concentrations, growth and carcass composition in finishing Friesian steers. J. Anim. Physiol. Anim. Nutr. 60:128-136.

Reynolds, C. K., H. F. Tyrrell, and P. J. Reynolds. 1991. Effects of diet forage-to-concentrate ratio and intake on energy metabolism in growing beef heifers: Whole body energy and nitrogen balance and visceral heat production. J. Nutr. 121:994-1003.

Robinson, J. B., D. R. Ames, and G. A. Milliken. 1986. Heat production of cattle adapted to cold, thermoneutrality, and heat when exposed to thermoneutrality and heat stress. J. Anim. Sci. 62:1434-1440.

Simmons, K. R., A. E. Dracy, and W. O. Essler. 1965. Diurnal temperature patterns in unrestrained cows. J. Dairy Sci. 48:1490-1493.

Sievers, A. K., N. B. Kristensen, H.-J. Laue, and S. Wolffram. 2004. Development of an intraruminal device for data sampling and transmission. J. Anim. Feed Sci. 13(Suppl. 1): 207-210.

Step, D. L., C. R. Krehbiel, H. A. DePra, J. J. Cranston, R. W. Fulton, J. G. Kirkpatrick, D. R. Gill, M. E. Payton, M. A. Montelongo, and A. W. Confer. 2008. Effects of commingling beef calves from different sources and weaning protocols during a forty-two-day receiving period on performance and bovine respiratory disease. J. Anim. Sci. 86:3146-3158.

Snowder, G. D., L. D. Van Vleck, L. V. Cundiff, and G. L. Bennett. 2006. Bovine respiratory disease in feedlot cattle: Environmental, genetic, and economic factors. J. Anim. Sci. 84:1999-2008.

Thrift, F. A., S. M. Keeney, and D. L. Applegate. 1994. Elevated body temperature differences expressed by stocker cattle processed through a Central Kentucky stockyard. Prof. Anim. Sci. 10:139-144.

Wrenn, T. R., J. Bitman, and J. F. Sykes. 1961. Diurnal patterns of bovine body temperature. J. Dairy Sci. 44:2077-2080.

CHAPTER II

USE OF REMOTE RUMINAL TEMPERATURE MONITORING TO IDENTIFY CATTLE AFFECTED WITH CLINICAL BOVINE RESPIRATORY DISEASE: RECEIVING PHASE PERFORMANCE AND HEALTH

ABSTRACT

Two lots of heifer calves (n = 366, mean initial BW = 243 ± 30 kg) originating from LA and OK, and OH were commingled and shipped to Stillwater, OK to study the effects of using ruminal temperature monitoring for detection of clinical bovine respiratory disease (**BRD**) on calf health and feedlot receiving performance. Heifers were administered remote ruminal temperature monitoring boluses and assigned to one of three experimental BRD management methods: Pulled based on visual signs of BRD (**CON**), administered metaphylaxis on d 0 and subsequently pulled based on visual signs of BRD (**MET**), or pulled based on visual signs of BRD or elevated ruminal temperature (**TEMP**). Performance and health of calves was evaluated over a 56-d receiving phase. Bronchoalveolar lavage (**BAL**) samples were obtained from calves at time of antimicrobial administration and from clinically healthy calves as supplies were available. A greater ($P < 0.01$) number of antimicrobials were administered using MET and TEMP methods compared to CON, when metaphylactic doses for MET heifers was included. After 28 d, MET had 2.5% heavier ($P = 0.04$) BW than CON. At 56 d TEMP

had 1.7% heavier ($P = 0.05$) BW than CON. Metaphylaxis increased ADG by 10.4% ($P = 0.01$) and G:F by 8.6% ($P = 0.03$) from d 0 to 56 over CON. Overall, ADG generally decreased as number of BRD treatments increased; however, overall ADG of TEMP heifers did not differ ($P \geq 0.60$) by times treated. During wk 2 and 3, ruminal temperatures of CON and MET heifers increased ($P \leq 0.05$) with increasing number of times identified with BRD, while temperatures of TEMP heifers were not different ($P \geq 0.90$) between those identified zero times or once. Lung lavage samples of clinically healthy MET heifers contained pathogenic species more frequently ($P = 0.04$) than TEMP, and BAL samples of clinically healthy CON heifers tended ($P = 0.06$) to contain *Mannheimia haemolytica* more frequently than TEMP. *Histophilus somni* was cultured from a greater ($P = 0.03$) percentage of CON heifers at time of first antimicrobial administration compared to MET and TEMP. Results indicate that metaphylaxis and ruminal temperature monitoring improve animal performance and temperature monitoring may assist in identification of subclinical BRD.

KEY WORDS: beef cattle, body temperature, bovine respiratory disease, performance, health

INTRODUCTION

In 2006, the National Agricultural Statistical Service conducted a report on cattle death loss in the United States, and determined that bovine respiratory disease (**BRD**) caused 1.11 million deaths, accounting for nearly 30% of all cattle deaths, more than any other cause. Digestive problems were the second leading cause at 17%. When

examining deaths in only feedlot cattle, BRD accounts for 50-70% of mortality and approximately 75% of morbidity (Chirase and Greene, 2000).

Respiratory death loss cost the industry an estimated $692 million (NASS, 2006). This figure does not account for losses due to treatment costs, diminished performance, and decreased carcass value. When considering these factors, BRD may have an economic impact of up to $900 million annually (Chirase and Greene, 2000). Schneider et al. (2009) determined that feedlot cattle returned $23.23, $30.15, and $54.01 less than healthy calves when treated once, twice or three or more times for BRD, respectively. Fulton et al. (2002) estimated that economic returns were even less in calves entering the feedlot in November. Calves treated once, twice, or more times for BRD returned $40.64, $58.35, and $291.93 less than healthy calves, respectively. Other costs to consider include time and labor required to identify sick calves and pulling and handling of these calves. With all of these factors considered, BRD is clearly the most medically and economically detrimental disease observed in feedlot cattle.

Bovine respiratory disease is a multi-factorial disorder in cattle, as there are numerous viral and bacterial species that compromise respiratory health in cattle. Interactions among these pathogens are largely responsible for morbidity and mortality (Panciera and Confer, 2010). Disease does not typically result from presence of only one bacterial specie; although, respiratory infections may be present as the result of infection by a single viral specie. Viruses that are typically implicated in BRD cases include bovine parainfluenza type 3 virus (**PI_3V**), bovine viral diarrhea virus (**BVDV**), bovine respiratory syncytial virus (**BRSV**), and bovine herpesvirus type 1 (**BHV-1**), which is a causative agent of infectious bovine rhinotracheitis virus (**IBR**). The main bacterial

species that cause BRD-related illness include *Mannheimia haemolytica, Pasteurella multocida,* and *Histophilus somni*.

Viruses such as PI_3V, BRSV, and BHV-1 are associated with damaged cells in the lining of the upper respiratory tract and overall impaired immunological function (Griffin, 1996). It is generally accepted that the onset of BRD is initiated with a viral infection of the upper respiratory tract, particularly by PI_3V and BRSV (Griffin, 1996). Bovine viral diarrhea virus is commonly implicated in cases of BRD, although not typically as a causative agent, but resulting in immunosuppression. Therefore, cattle exposed to BVDV may be more susceptible to BRD pathogens due to decreased immune function (Ridpath, 2010).

Damaged cells and inflammation resulting from viral infection allow bacterial pathogens to attack the lower respiratory tract. Viruses may also infect the terminal bronchi of the lung, causing inflammation, coughing, and potentially edema and emphysema (Griffin, 1996). Calves that are weaned immediately prior to shipment and arrival into the feedlot are especially stressed, further suppressing the immune system. Other stressors such as extreme heat or cold, and presence of dust in the air may also impair the immune function of the calf, increasing its susceptibility to various pathogens.

Mannheimia haemolytica is commonly implicated in cases of BRD, and it has been isolated in calves suffering from BRD more often than any other bacterial species, particularly in fatal cases (Griffin et al., 2010; Katsuda et al., 2008). This bacterium can cause necrosis, fibrin accumulation, edema, and lesions indicative of vascular damage. An exotoxin produced by this bacterium can peak within six hours of infection. A specific exotoxin, commonly called leukotoxin, produced by this bacterium is then

responsible for killing macrophages and neutrophils produced by the host. The cascade of events will cause damage of cellular membranes by enzymes and oxidants, resulting in increased permeability of capillaries. Accumulation of fluid in the alveolar walls occurs, resulting in necrosis of the alveoli and pulmonary edema (Griffin, 1996).

Pasteurella multocida in calves affected with BRD is not as frequently isolated as *M. haemolytica*, but is still commonly considered in BRD-related illness. *Pasteurella multocida* has been the most common bacterial isolate in some populations of calves (Chen et al., 2003), although this occurrence is rare. *Pasteurella multocida* also does not appear to cause as much damage as *M. haemolytica*, but may still be lethal in very young, highly-stressed calves. There is some evidence that *P. multocida* isolates may be increasing in frequency in fatal cases of BRD (Griffin et al, 2010).

Histophilus somni also plays a critical role in BRD-related illness. These bacteria are facultative, meaning they can survive in the presence of oxygen. Therefore, it is particularly difficult for the animal to fight this bacterium using natural immunological mechanisms (Griffin, 1996). *Histophilus somni* may gain entry into the systemic circulation and may adhere to the vascular endothelium, resulting in inflammation of the blood vessels and development of blood clots. Decreased blood supply to affected areas may cause tissue death in localized regions (Griffin, 1996).

While BRD is the most common cause of feedlot morbidity, cattle with subclinical disease do not exhibit clinical signs or are undetected, and therefore, are not treated. Researchers have examined lung lesions of beef cattle at harvest to quantify the degree of BRD incidence, as lesions will be evident in cattle that have experienced both clinical and subclinical BRD. Wittum et al. (1996) conducted a study using 469 steers

originating from the Meat Animal Research Center (**MARC**) in Nebraska. Steers identified with clinical BRD were treated with antimicrobials if rectal temperature was at least 39.7°C. Of the 469 steers, 35% received treatment for BRD. At harvest, however, 72% of steers had lung lesions consistent with BRD. Additionally, of the steers not treated for BRD, 68% had lung lesions. Average daily gains of the unidentified BRD steers with lung lesions were 0.076 kg less than that of steers without lesions. The authors concluded that traditional BRD assessment methods are not adequate in identifying affected calves.

Bryant et al. (1999) conducted a study that utilized 439 calves originating from MARC. Additionally, 599 calves from Montana, Nebraska, and auction markets in Oklahoma and Texas were utilized. All calves were fed in Nebraska or Kansas. Of calves originating from MARC, 17% received treatment for BRD, while 42% had lung lesions present at slaughter. The authors distinguished between locations of lesions, attributing cranioventral lesions with bronchopneumonia. These lesions were associated with ADG of 0.03 kg less compared to cattle without lesions. In the other group of 599 calves, 54% had lung lesions present at harvest, but only 30% were located on the cranioventral lobes. Average daily gains of calves with cranioventral lesions were between 0.06 and 0.30 kg less than claves without lesions, depending on the home pen. Data regarding frequency of antimicrobial treatment were not provided for this group of calves. However, similar to Wittum et al. (1996), the authors noted that BRD diagnostic methods are likely inadequate.

Other researchers conducted an experiment involving 204 feedlot steers originating in South Dakota and fed in Kansas was conducted to determine the

relationship between lung lesions at harvest with feedlot performance (Gardner et al., 1999). Steers observed with clinical signs consistent with BRD were treated with antimicrobials when rectal temperature was at least 40°C, with 50% of calves receiving treatment. Only 43% of lungs had lesions present; however, distribution of these lesions was similar between calves that had been treated and those that had not. Steers that had lung lesions present at harvest also had lower ADG, HCW, and marbling compared to steers without lung lesions. The authors concluded that presence of lung lesions was more closely related to feedlot performance and carcass measures compared to frequency of antimicrobial treatment.

A study was conducted using 170 feedlot heifers originating from auction markets in the Southeast and subsequently fed in Texas (Buhman et al., 2000). Of these, 43% were treated for BRD, while 87% had lung lesions present at harvest. Additionally, 83% of calves that had never been identified as sick had lung lesions recorded at harvest.

An experiment conducted in South Africa utilized 2,036 calves, which were treated for BRD when rectal temperature was at least 40°C and clinical signs were evident (Thompson et al., 2006). At slaughter, lung lesions were present in 43% of calves. Of the animals never treated for BRD, 39% had lung lesions at slaughter. However, of all animals with lung lesions present, 70% had never been treated. In cases of animals treated once or at least twice for BRD, frequency of lung lesion presence was 55% and 67%, respectively. Overall, combined information from treatment records and lung scores, incidence of BRD was estimated to be 53%. However, only 23% of all calves were treated for BRD.

Reinhardt et al. (2009) obtained data from more than 20,000 feedlot calves. It was assumed that a majority had been preconditioned prior to entering the feedlots, which were located in Iowa. When calves exhibited clinical signs of BRD, they were administered an antimicrobial if their rectal temperature was at least 39.7°C. Lungs were observed at harvest in a subset of 6,826 calves, and lung lesions were only present in 3.9%. In these calves, lung lesions were associated with lower ADG, HCW, and LM area. Calves that had lung lesions present at harvest were also treated more frequently (0.12 times per calf) than calves without lesions. Cattle with no evidence of lung lesions had been treated for clinical BRD at a rate of 0.07 times per calf. The presence of lung lesions at harvest was much lower in this study compared to others. This may support the practice of preweaning and preconditioning, as incidence of morbidity and lung lesions was drastically reduced in this study compared to results from non-preconditioned calves presented by others.

A project conducted by Schneider et al. (2009) utilized data from nearly 6000 feedlot calves. Lung lesion scores were obtained from 1,665 of these calves. Incidence of BRD was observed in 8.2% of the overall population, while 62% of observed lungs had lesions. These findings led the authors to estimate that overall actual incidence of BRD was 64%. Cattle affected with clinical BRD had lower ADG both during the receiving phase and throughout the entire feeding phase. Carcass traits, including HCW and marbling scores, were also negatively impacted by BRD. Contrary to other studies, the authors did not observe a relationship between presence of lung lesions and performance and carcass traits. However, they did note a relationship between these traits and active lymph nodes.

There is overwhelming evidence that BRD persists as a great cause of biological and economic losses in feedlot cattle despite introduction of new viral and bacterial preventive and therapeutic pharmaceuticals. Therefore, novel methods of BRD detection may benefit the feedlot industry by improving the health and well-being of feedlot cattle, while also lessening the economic burden of the disease. Remote ruminal temperature monitoring has the potential to assist in detection of BRD. Rose-Dye et al. (2011) challenged beef steers with bovine viral diarrhea virus and *Mannheimia haemolytica*, and observed that ruminal temperatures increased in response to challenge. In naturally infected cattle, ruminal temperature increased with the number of times calves were treated for BRD (Sims et al., 2009). Therefore, it is hypothesized that use of remote ruminal temperature monitoring may be used to identify calves suffering from BRD. The objective of this experiment was to determine if ruminal temperature assists BRD detection, improves performance, improves health, and reduces ruminal temperature of newly received feedlot calves.

MATERIALS AND METHODS

All procedures were approved by the Oklahoma State University Institutional Animal Care and Use Committee.

Cattle

This experiment was conducted on two lots of heifer calves. The first lot consisted of 148 British × *Bos indicus* calves that were purchased in Prairieville, LA in May, 2009 plus 38 British and British crossbred calves that were purchased in El Reno,

OK. The second lot consisted of 180 British and British crossbred calves that were purchased in Hillsboro, OH in September of 2009.

At the purchase facilities in LA and OH, heifers were administered a unique identification ear tag and a remote ruminal temperature monitoring bolus (Strategic Solutions International, Stillwater, OK). Heifers were then transported to the Willard Sparks Beef Research Center (**WSBRC**) in Stillwater, OK (1112 km from the LA location, 1424 km from the OH location). Heifers purchased in El Reno, OK were shipped 146 km to WSBRC, and were administered a temperature monitoring bolus and identification ear tag on arrival.

Upon arrival, calves were allowed to rest for approximately 1 h without access to feed or water, and were then individually weighed (mean = 246.4 ± 29.9 kg), and ear notch samples were obtained to test for persistent infection with bovine viral diarrhea virus (**PI-BVDV**, Oklahoma Animal Disease Diagnostic Laboratory). Calves were allowed to commingle across six pens (12.2 × 30.5 m, 12.2 m of bunk space), and were offered water and long-stemmed prairie ad libitum hay until initial processing, which was 48-72 h later.

At initial processing (d 0), calves were administered a clostridial vaccine (Vision 7 with Spur, Intervet/Schering-Plough, DeSoto, KS), a deworming treatment (Ivomec Plus Injectable, Merial, Duluth, GA), and an implant containing estradiol and trenbalone acetate (Component TE-G, Vetlife, Overton Park, KS), and were dehorned when necessary. Heifers were also administered a viral pathogen vaccine. Those from the LA and OK locations were administered Vista 5 SQ (Intervet/Schering-Plough) at initial

processing and Express 5 (Boehringer Ingelheim, St. Joseph, MO) on d 14, and those from the OH location received Express 5 at initial processing and 14 d later.

Calves were blocked by BW, stratified by coat color, and randomly allotted to one of 24 pens (12 within each lot), which had been randomly assigned to one of three BRD management methods: Pulled based on visual signs of BRD (**CON**), administered a metaphylactic dose of tulathromycin (2.5 mg/kg BW; Draxxin, Pfizer Animal Health, Exaton, NY) at processing and subsequently pulled based on visual signs of BRD (**MET**), or pulled based on visual signs or elevated ruminal temperature (**TEMP**).

Heifers were maintained on a 63% concentrate diet (Table 2.1), which was offered ad libitum. Trained personnel read the bunks each morning, and made a daily call. Feed was delivered to the bunks each morning after the morning call and in the afternoon. Individual BW were obtained on d 14, 28, 42, and 56. Feed refusals were collected at the end of each 14 d period.

Ruminal Temperature Monitoring

When calves arrived at WSBRC, temperature monitoring boluses reported current ruminal temperature to a remote computer. Boluses first transmitted signals to fixed transceiver stations, which were specifically designed to receive bolus signals, located above the middle of each pen's feed bunk, above the middle of the back fence line of each pen, and above each automatic water unit, which were located along the side fence line and shared between adjacent pens. Transceiver stations then reported bolus data to a separate transceiver station, designed to relay and receive data. Finally, data signals were sent via this transceiver to a fixed transceiver station equipped with a USB serial

connection, which logged temperature data in a database. Boluses were also designed to store temperature data. At harvest, 75% of the boluses were collected, and stored data were used for analysis. Data collected by transceivers were utilized for the remaining 25%.

Temperature data were evaluated for each heifer, and water drinking events were identified and removed from the data set prior to statistical analysis. The beginning of a drinking event was identified by a temperature decrease of at least 0.28°C from the previous measurement. The end of the water drinking event was identified when temperature either ceased to increase over a 10 min time span, or increased to the last temperature observed prior to the drinking event. After removing water-associated temperatures from the data set, average and maximum daily temperatures were determined from 0700 to 0700 for each heifer.

Identification of and Treatment for BRD

Ruminal temperatures of TEMP heifers were examined at 0700 each morning. Heifers were pulled based on criteria in the Tru-Tag System (Strategic Solutions International) that included sustained temperature thresholds as well as maximum daily temperature thresholds. All heifers were visually evaluated each morning at approximately 0700 for signs of BRD by two trained individuals who were blinded to experimental management methods. Criteria for visual pulls were based on the DART system (Pharmacia & Upjohn Animal Health, Kalamazoo, MI). Clinical signs of BRD included depression (D; hanging head, sunken eyes, drooping ears, stiffness), appetite (A; lack of fill compared to penmates, off feed, eating less than or with less aggression than

penmates), and respiratory signs (R; labored breathing, extended neck and head, noisy breathing). Calves exhibiting one or more of these signs were assigned a severity score of 1 (mild), 2 (moderate), 3 (severe), or 4 (moribund). Calves receiving a severity score of 1 to 4 and calves pulled based on elevated ruminal temperature were brought to the handling facility for further evaluation. Rectal temperature and BW were recorded for each pull. Heifers with severity scores of 1 or 2 and those pulled based on ruminal temperature were treated with an antimicrobial if rectal temperature was ≥ 40°C, and heifers with severity scores of 3 or 4 were treated regardless of rectal temperature.

The treatment regimen for BRD consisted of three antimicrobials. Tulathromycin was considered the first antimicrobial treatment for MET heifers, and was also used as a first treatment for CON and TEMP heifers. Heifers were not eligible for a second antimicrobial treatment until 7 d after receiving tulathromycin, unless a severity score of 3 or 4 was assigned, in which case heifers were eligible for a second treatment after 4 d. The second antimicrobial used was enrofloxacin (10 mg/kg BW, Baytril, Bayer Animal Health, Shawnee Mission, KS). After receiving the second antimicrobial, heifers were not eligible for the third antimicrobial until 48 h later. The third treatment consisted of two doses of ceftiofur hydrochloride (2.2 mg/kg BW, Excenel, Pfizer Animal Health) that were administered 48 h apart.

Bronchoalveolar Lavage Sampling

Bronchoalveolar lavage (**BAL**) samples were obtained from heifers identified with BRD prior to antimicrobial administration, as supplies were available. Three MET heifers within each pen were randomly selected to be sampled at processing prior to

administration of metaphylaxis, resulting in 24 BAL samples from MET heifers at the time of first antimicrobial administration (at processing). When a BAL was obtained from a heifer identified with BRD, BAL samples were also obtained from two clinically healthy calves belonging to the same experimental management method. To obtain samples, heifers were restrained in a squeeze chute and cross ties were used to position the head so that the heifer's nose was elevated. Then, samples were obtained by inserting a sterile 240 cm-long BAL tube (Broncho-alveolar lavage equine catheter J639, Jorgensen Laboratories, Loveland, CO) equipped with a three-way stop cock into one of the nares. The BAL tube was passed through the trachea, past the tracheal bifurcation, into a distal lung lobe, and the area was sealed by inflating the cuff with approximately 10 mL of air. A 60 mL syringe containing 0.9% sterile saline solution was attached to the stopcock, which was then opened to allow instillation of saline. Solution was immediately aspirated, and the process of instilling and aspirating was repeated two more times with fresh syringes of sterile solution each time, for a total of three aliquots of 60 mL each. Retrieval was typically 50 – 75% of the amount instilled. Aliquots were combined, placed in a cooler with either ice or an ice pack, and transported to the laboratory for bacterial and mycoplasma analysis.

At the laboratory, swabs from each BAL sample were streaked across a BBL Columbia sheep blood agar plate (Becton Dickinson, Sparks, MD) and a *Mycoplasma* agar plate (UC Davis Biological Media Services, Davis, CA). Plates were incubated at 37°C in 7% CO_2 for 24 h for blood agar plates, and up to 10 d for mycoplasma plates. Colonies that grew on blood agar plates with morphology typical of BRD-causing organisms (*Mannheimia haemolytica*, *Pasteurella multocida*, *Archanobacterium*

pyogenes, and *Histophilus somni*) were isolated, and 3% H_2O_2 catalase and oxidase (Becton Dickinson) tests were performed. If organisms reacted appropriately, organisms were identified using the Sensititre™ GNID panel (Trek Diagnostic Systems, Cleveland, OH). Samples that grew colonies on *Mycoplasma* plates that were typical of *Mycoplasma* were considered to be positive for *Mycoplasma* spp.

Statistical Analysis

To determine differences between BRD management methods of CON, MET, and TEMP, performance data were analyzed using the MIXED procedure of SAS (SAS Institute, Cary, NC), and temperature data were analyzed using the GLIMMIX procedure of SAS. Pen was considered the experimental unit, and the fixed effect was BRD management method. For temperature data, week and the interaction of week and method were also included in the model as fixed effects. Random effects included lot, weight block, and pen within treatment. Temperature data were analyzed as a repeated measure with day as the repeated subject using an autoregressive structure. The covariance structure in both analyses was selected by subjecting the model to multiple covariance structures, and the best fit model was selected to contain the covariance structure that yielded the smaller Akaike's and Schwarz's Bayesian criteria based on their −2 res log-likelihood.

In order to determine effects of BRD management method and severity of BRD, two techniques of data analysis were utilized. The first approach was developed from a management perspective. In this approach, the number of times calves were identified with BRD, pulled from their pen, and administered an antimicrobial were considered.

For CON and TEMP methods, the number of times calves were identified with and treated for BRD was the same as the number of antimicrobials administered. For the MET method, heifers only receiving metaphylaxis were considered to have never been identified with and treated for BRD; those that received enrofloxacin were considered to have been identified with BRD once, and those that received ceftiofur-HCl were considered to have been identified with BRD twice. This resulted in categories of zero, one, and two for number of times calves were identified with and treated for BRD. Heifers assigned to CON and TEMP methods that were identified with BRD three times were omitted from this analysis, thus creating a 3 × 3 factorial arrangement of management method (CON, MET, TEMP) and number of times calves were identified with and treated for BRD (zero, one, two).

The second approach was developed from an economic perspective. In this approach, the number of antimicrobials administered was considered, including the metaphylactic dose administered to MET heifers. Calves assigned to CON and TEMP methods that were never identified with BRD, and thus never received an antimicrobial, were omitted from this analysis. There was only one CON heifer that was administered three antimicrobials; therefore, this heifer was eliminated from the analysis, resulting in a 3 × 3 factorial of management method (CON, MET, TEMP) and number of antimicrobials administered (one, two, three) with one missing combination (CON, three).

For both approaches, data were analyzed using the GLIMMIX procedure of SAS. Main effects included BRD management method, category of BRD therapy, and the interaction of the two. For these analyses, individual animal was considered the

experimental unit, and random effects included lot, weight block, pen, and animal within lot, weight block, and pen. Response variables for these analyses were limited to those that could be measured individually, including BW, ADG, and ruminal temperature. Reported temperature values are average and maximum daily temperature during each of the 8 weeks of the experiment.

Results from BAL samples were determined using the GLIMMIX procedure of SAS. Data were summarized by category of BRD classification (clinically healthy, time of first antimicrobial administration, or time of second antimicrobial administration) within each pen. Number of pathogenic species isolated and type of pathogenic species isolated were analyzed as a binomial distribution with the main effect of management method and random effects of lot, weight block, and animal within pen.

When effects were significant at the $P \leq 0.05$ level, least squares means were separated by pairwise comparison using the PDIFF option. Differences are discussed when $P \leq 0.05$, and considered tendencies when $0.05 < P \leq 0.10$.

RESULTS

It was determined that no calves from either lot were positive for PI-BVDV. Of the first lot of 186 heifers, one died of bronchopneumonia, which was confirmed at postmortem examination, one was removed from the project due to causes related to BRD, and four were removed from the project due to lameness. Of the second lot of 180 heifers, 167 were selected to be enrolled in the project. Selected calves were those not requiring treatment for BRD on arrival. Of these selected calves, one died of bronchopneumonia, which was confirmed at postmortem examination, two were removed

from the project due to causes related to BRD, one was removed due to lameness, and one was removed due to injury. Available data for heifers removed from the project due to BRD-related causes were included in the analyses.

Morbidity of Heifers

The frequency of times pulled and times treated for BRD are shown in Table 2.2. Heifers managed with the temperature monitoring method were pulled from their pens nearly 5 times more often ($P < 0.01$) than CON and MET heifers which were not different ($P = 0.26$). Heifers managed with the TEMP method were treated for BRD 0.88 times more often ($P < 0.01$) than CON, which were treated 0.32 times more often ($P = 0.05$) than MET when not accounting for the metaphylactic dose of tulathromycin administered to MET heifers. When accounting for metaphylaxis, the frequency of drug administration was not different ($P = 0.17$) between MET and TEMP heifers, which were treated 2.3 more times per heifer ($P < 0.01$) compared to CON. The percentage of heifers that were treated for BRD following a pull was not affected ($P = 0.11$) by BRD management method. Mortality of heifers was not analyzed statistically, but 3 heifers managed with the CON method, 3 heifers managed with the TEMP method, and zero heifers managed with the MET method died of causes related to BRD. The distributions of timing of antimicrobial administration for each of the three management methods are shown in Figures 2.1, 2.2, and 2.3. A majority of first administrations for CON and TEMP heifers, and a majority of second administrations for MET heifers occurred during the first 14 d. Timing of all antimicrobial administrations was spread across 34 days for CON, 50 days for MET, and 55 days for TEMP.

Performance

Overall effect of management method. Initial and 14 d BW were not different ($P \geq 0.29$) among management methods (Table 2.3). On d 28, BW of MET heifers was 7.3 kg greater ($P = 0.04$) compared to heifers exposed to the CON method. On d 42, no differences ($P = 0.15$) in BW were observed. At the completion of the receiving phase on d 56, BW of heifers exposed to the TEMP method were 5.2 kg greater ($P = 0.05$) than CON heifers. Additionally, heifers exposed to the MET method tended ($P = 0.07$) to weigh 3.9 kg more than CON heifers on d 56.

There was a tendency ($P = 0.06$) for management method to affect ADG during the first 14 d, with MET heifers gaining 0.61 kg more per d compared to CON. Gains of TEMP heifers during this time were not different ($P \geq 0.14$) from the other management methods. No differences ($P \geq 0.24$) were observed in ADG during any of the other 14-d periods of the receiving phase. However, overall ADG across the entire 56-d period were 0.12 kg/d greater ($P < 0.01$) in heifers exposed to the MET method compared to CON. Gains of TEMP heifers also tended ($P = 0.07$) to be 0.07 kg/d greater than CON heifers across the entire receiving phase.

Dry matter intake did not differ ($P \geq 0.31$) among the three management methods during any of the four 14-d periods or across the entire 56-d experiment. However, due to differences in ADG, G:F was similarly affected by management method. During the first 14 d, gain efficiencies tended ($P = 0.10$) to be 41% greater in heifers exposed to the MET method compared to CON. During the entire 56-d experiment, gain efficiencies were improved 8.6% ($P = 0.03$) for MET heifers over CON, and tended ($P = 0.10$) to be improved by 5.1% for TEMP heifers over CON.

Effects of management method and times identified with and treated for BRD.

Bodyweight and ADG results for CON, MET and TEMP heifers identified with BRD zero, one, or two times are shown in Table 2.4. At the initiation of the experiment, heifers that would be identified with BRD 0, 1, or 2 times did not exhibit differences ($P = 0.60$) in BW. However, d 14 and 28 BW were affected ($P \leq 0.02$) by management method and number of times calves were pulled and treated for BRD. On d 14, heifers managed with MET weighed 10.6 kg more ($P < 0.01$) than CON, and heifers never identified with BRD weighed 9.2 kg more ($P = 0.02$) than those identified with BRD once or twice. On d 28, heifers managed with MET weighed 13.7 kg more ($P < 0.01$) than CON, and heifers never identified with BRD weighed 12.7 kg more ($P \leq 0.01$) than those identified with BRD once or twice. On d 42 and 56, BW showed an interaction ($P \leq 0.04$) between management method and number of times calves were identified with BRD. On d 42, heifers managed with the CON method and never identified with BRD weighed 38.8 kg more ($P < 0.01$) than those identified with BRD twice, heifers managed with the MET method and never identified with BRD weighed 22.4 kg more ($P < 0.01$) than those identified with BRD twice, and BW did not differ ($P \geq 0.49$) among TEMP heifers identified with BRD zero, one, or two times. On d 56, heifers managed with the CON method and never identified with BRD weighed 13.5 kg more ($P = 0.01$) than those identified once, which weighed 26.1 kg more ($P < 0.01$) than those identified twice. Among MET heifers, BW of those never identified with BRD weighed 19.9 kg more ($P = 0.02$) than those identified twice. Number of times identified with BRD did not affect ($P \geq 0.76$) BW of TEMP heifers. Among heifers identified with BRD twice, TEMP heifers weighed 30.2 kg more ($P \leq 0.03$) than CON and MET.

From d 0 to 14, ADG showed an interaction ($P = 0.02$) of management method and number of times identified with BRD. Heifers managed with the CON method and identified with BRD twice gained 0.96 kg/d less ($P \leq 0.04$) than those identified zero or one times. Number of times identified with BRD did not affect ($P \geq 0.25$) d 0 to 14 ADG of MET and TEMP heifers. Among heifers identified with BRD twice, those managed with the CON method gained 1.37 kg less ($P < 0.01$) than those managed with the MET and TEMP methods. From d 14 to 28, there was a tendency ($P = 0.06$) for ADG of heifers identified with BRD twice to be 0.40 kg/d less than those identified zero or one times. From d 28-42, heifers identified with BRD twice gained 0.53 kg/d less ($P < 0.01$) than those identified once, and tended ($P = 0.06$) to gain 0.34 kg/d less than those never identified with BRD. Across the entire receiving phase from d 0 to 56, there was an interaction ($P < 0.01$) between management method and number of times identified with BRD. Among heifers managed with the CON method, those identified with BRD twice gained 0.58 kg/d less ($P < 0.01$) than those identified zero or one time. Among heifers managed with the MET method, those never identified with BRD gained 0.16 kg/d more ($P = 0.02$) than those identified twice. Among heifers managed with the TEMP method, no differences ($P \geq 0.60$) were observed due to number of times identified with BRD. There were no differences ($P \geq 0.27$) among management methods in heifers never identified with BRD. Of heifers identified with BRD once, those managed with the TEMP method gained 0.14 kg/d more ($P = 0.05$) than those managed with the CON method. Of heifers identified with BRD twice, those managed with the MET and TEMP methods gained 0.56 kg/d more ($P < 0.01$) than those managed with the CON method.

Effects of management method and number of antimicrobials administered.

Bodyweight and ADG results for CON, MET and TEMP heifers administered one, two, or three antimicrobials are shown in Table 2.5. At the initiation of the experiment, heifers that would be administered one, two, or three antimicrobials did not exhibit differences ($P = 0.99$) in BW. On d 14, BW was affected ($P = 0.02$) by management method. Heifers managed with the CON method weighed 13.5 kg less ($P < 0.01$) than those managed with the MET and TEMP methods. On d 28, 42, and 56, BW was affected ($P < 0.01$) by management method and number of antimicrobials administered. On d 28, MET and TEMP heifers weighed 13.9 kg more ($P < 0.01$) than CON, and heifers administered one antimicrobial weighed 8.8 kg more ($P < 0.01$) than those administered two or three. On d 42, MET and TEMP heifers weighed 15.9 kg more ($P < 0.01$) than CON, and heifers administered one antimicrobial weighed 14.1 kg more ($P < 0.01$) than those administered two or three. On d 56, TEMP heifers weighed 22.4 kg more ($P < 0.01$) than CON while MET heifers were intermediate, and heifers administered one antimicrobial weighed 11.9 kg more ($P < 0.01$) than those administered one or two.

From d 0 to 14, ADG showed an interaction ($P = 0.03$) of management method and number of antimicrobials administered. Among heifers managed with the CON method, those administered one antimicrobial gained 0.72 kg/d more ($P = 0.01$) than those administered two, while ADG did not differ ($P \geq 0.11$) by number of antimicrobials administered in MET and TEMP heifers. Among those administered one antimicrobial, CON heifers gained 0.83 kg/d less ($P = 0.04$) than MET heifers. Among those administered two antimicrobials, CON heifers gained 1.34 kg/d less ($P < 0.01$) than MET

and TEMP heifers. Gains of MET and TEMP heifers administered three antimicrobials did not differ ($P = 0.52$). From d 14 to 24, heifers administered one antimicrobial gained 0.41 kg/d more ($P < 0.01$) than those administered two or three. From d 28 to 42, there was a tendency ($P = 0.10$) for management method to affect ADG, and ADG was also affected ($P < 0.01$) by number of antimicrobials administered. Heifers managed with the TEMP method tended ($P = 0.10$) to gain 0.31 kg/d more than those managed with the MET method. Heifers administered one antimicrobial tended ($P = 0.10$) to gain 0.24 kg/d more than those administered two, and gained 0.45 kg/d more ($P = 0.04$) than those administered three. Across the entire receiving period from d 0 to 56, ADG showed an interaction ($P < 0.01$) of management method and number of antimicrobials administered. Among heifers managed with the CON method, those administered one antimicrobial gained 0.53 kg/d less ($P < 0.01$) than those administered two. Among MET heifers, those administered three antimicrobials tended ($P = 0.08$) to gain 0.23 kg/d less than those administered one. Among TEMP heifers, those administered one or two antimicrobials gained 0.23 kg/d more ($P \leq 0.03$) than those administered three. Of heifers administered one antimicrobial, heifers managed with the CON method gained 0.17 kg/d less ($P = 0.03$) than those managed with the MET method, and tended ($P = 0.07$) to gain 0.14 kg/d less than heifers managed with the TEMP method. Of heifers administered two antimicrobials, those managed with MET and TEMP methods gained 0.46 kg/d more ($P < 0.01$) than CON.

Ruminal Temperature

Overall effect of management method. The effects of management method on maximum and average daily ruminal temperatures are shown in figures 2.4 and 2.5, respectively. There was an interaction ($P < 0.01$) of management method and wk for maximum daily ruminal temperature. During wk 1, maximum daily temperatures of heifers administered metaphylaxis was 0.22°C less ($P < 0.01$) than heifers managed with CON and TEMP methods. However, by week 2, maximum daily temperature of TEMP heifers decreased by 0.28°C, such that maximum temperatures of these heifers were not different ($P = 0.19$) than MET. Maximum temperatures of CON heifers were 0.21°C higher ($P < 0.01$) than MET and TEMP during wk 2. During wk 3, maximum temperatures of CON heifers were 0.14°C higher ($P < 0.01$) than temperatures of TEMP heifers, and temperatures of MET heifers were intermediate. During wk 5, temperatures of MET heifers had increased such that maximum daily temperatures of these heifers were 0.11°C higher ($P = 0.03$) than TEMP, and CON heifers were intermediate. During wk 6, temperatures of MET heifers tended ($P = 0.10$) to be 0.08°C higher than CON, and during wk 8, temperatures of MET heifers tended ($P = 0.09$) to be 0.09°C higher than TEMP.

Average daily ruminal temperature also showed a management method by week interaction ($P < 0.01$). During wk 1, average temperatures of CON heifers were 0.06°C higher ($P = 0.05$) than TEMP heifers, whose temperatures were 0.16°C higher ($P < 0.01$) than MET heifers. During wk 2, average temperatures of CON heifers were 0.18°C higher ($P < 0.01$) than MET and TEMP heifers, which were not different ($P = 0.36$). During wk 3, average temperatures of CON heifers were 0.09°C higher ($P \leq 0.05$) than

MET and TEMP heifers, which were not different ($P = 0.11$). During wk 4, average temperatures of MET heifers tended ($P = 0.09$) to be 0.05°C higher than TEMP heifers. During wk 5, average temperatures of MET heifers tended ($P = 0.09$) to be 0.06°C higher than CON heifers and were 0.08°C higher ($P < 0.01$) than TEMP heifers. During wk 6, average temperatures of MET heifers were 0.08°C higher ($P \leq 0.03$) than temperatures of CON and TEMP heifers. During wk 8, average temperatures of MET heifers tended ($P = 0.09$) to be 0.06°C higher than TEMP heifers.

Effects of management method and times identified with and treated for BRD.

Maximum and average daily ruminal temperatures of heifers managed with CON, MET, and TEMP methods and identified with BRD zero, one, or two times are shown in Table 2.6. During wk 1, management method and number of times identified with BRD affected ($P \leq 0.05$) maximum daily temperature of heifers. Heifers managed with the CON method had 0.18°C higher ($P = 0.02$) temperatures than TEMP, and tended ($P = 0.09$) to have 0.13°C higher temperatures than MET. Heifers never identified with BRD had 0.23°C lower ($P < 0.01$) temperatures than those identified once, and heifers identified with BRD once had 0.18°C lower ($P < 0.01$) temperatures than those identified twice. During wk 2 and 3, maximum daily temperature showed a management method by number of times identified with BRD interaction ($P < 0.01$). Temperatures generally increased with increasing number of times identified with BRD; however, maximum temperatures of TEMP heifers were often lower than their CON counterparts. In the final wk of the experiment, maximum temperatures of CON and TEMP heifers never identified with BRD were 0.14°C lower ($P \leq 0.02$) than temperatures of MET heifers

never identified with BRD. Among heifers identified with BRD once, maximum temperatures of MET heifers were 0.20°C higher ($P < 0.01$) than CON, and maximum temperatures of CON heifers were 0.15°C higher ($P < 0.01$) than TEMP. Among heifers identified with BRD twice, maximum temperatures of CON heifers were 0.21°C higher ($P = 0.01$) than TEMP, and tended ($P = 0.09$) to be 0.16°C higher than MET.

Average daily ruminal temperatures of heifers during wk1 were affected ($P \leq 0.02$) by management method and number of times identified with BRD. Average temperatures of CON heifers were 0.17°C higher ($P < 0.01$) than MET and TEMP heifers. Average temperatures of heifers identified with BRD zero times were 0.19°C lower ($P < 0.01$) than those identified once, which had 0.23°C lower ($P < 0.01$) temperatures than those identified twice. There was an interaction ($P < 0.01$) of management method and number of times identified with BRD during wk 2 and 3. Average temperatures of CON and MET heifers increased as the number of times identified with BRD increased, while average temperatures of TEMP heifers were only increased in those identified twice ($P \leq 0.05$). Management method and times identified with BRD affected ($P \leq 0.01$) average daily ruminal temperature of heifers. In wk 4, temperatures of CON and MET heifers were greater ($P \leq 0.05$) than TEMP, and in wk 5 and 6, temperatures of MET heifers were greater ($P \leq 0.05$) than TEMP while CON heifers were intermediate. During wk 4, 5, and 6 temperatures of heifers never identified with BRD and heifers identified with BRD once were lower ($P \leq 0.05$) than temperatures of heifers identified twice. There were interactions ($P < 0.01$) of management method and number of times identified with BRD for average daily temperature during wk 7 and 8. In wk 7, average temperatures of MET heifers never identified with BRD was 0.09°C

greater ($P < 0.01$) than TEMP heifers never identified. Also, temperatures of TEMP heifers identified with BRD once were 0.15°C lower ($P < 0.01$) than CON and MET heifers identified once. In wk 8, TEMP heifers never identified with BRD had 0.13°C lower ($P < 0.01$) temperatures than MET heifers that were never identified, and TEMP heifers identified once had 0.18°C lower ($P < 0.01$) temperatures than CON and MET heifers identified once.

Effects of management method and number of antimicrobials administered.

Maximum daily ruminal temperatures of heifers managed with CON, MET, and TEMP methods and administered one, two, or three antimicrobials are shown in Table 2.7. During wk 1, maximum daily temperature was affected ($P \leq 0.04$) by management method and number of antimicrobials administered. Heifers managed with the CON method had 0.25°C higher ($P = 0.04$) temperatures compared to MET. Heifers administered three antimicrobials had 0.11°C higher ($P = 0.05$) temperatures compared to those administered two, which had 0.17°C higher ($P < 0.01$) temperatures compared to those administered one. There were interactions ($P < 0.01$) between management method and number of antimicrobials administered during wk 2, 4, 5, 7 and 8. In wk 2, maximum temperatures increased ($P < 0.01$) with increasing number of antimicrobials administered in CON and TEMP heifers. Temperatures of MET heifers administered two and three antimicrobials were 0.36°C higher ($P < 0.01$) than those administered one. Maximum temperatures of MET and TEMP heifers administered one antimicrobial were not different ($P = 0.88$), but were 0.36°C lower ($P < 0.01$) than CON heifers administered one antimicrobial. At the midpoint of the experiment during wk 4 and 5, maximum

temperatures of heifers generally increased with increasing number of antimicrobials administered. Heifers managed with the TEMP method and administered one antimicrobial had 0.23°C lower ($P < 0.01$) temperatures compared to MET heifers administered one antimicrobial. At the end of the experiment at wk 8, number of antimicrobials administered did not affect ($P = 0.11$) maximum temperature of CON heifers. Among MET heifers, maximum temperature was 0.21°C higher ($P \leq 0.01$) in heifers administered two antimicrobials compared to those administered one or three, which were not different ($P = 0.83$). Among TEMP heifers, those administered one and two antimicrobials had 0.34°C lower ($P < 0.01$) temperatures compared to TEMP heifers administered three. Of heifers administered one antimicrobial, maximum temperatures of TEMP heifers were 0.15°C lower ($P \leq 0.03$) than CON and MET. Of heifers administered two antimicrobials, maximum temperatures of TEMP heifers were 0.27°C lower ($P < 0.01$) than MET, and tended ($P = 0.06$) to be 0.17°C lower than CON. Among heifers administered three antimicrobials, maximum temperatures of TEMP heifers were 0.25°C higher ($P = 0.01$) than MET.

During wk 1 and 2, average ruminal temperatures showed an interaction ($P \leq 0.03$) between management method and number of antimicrobials administered. Temperatures generally increased with increased number of antimicrobials; however, temperatures of CON heifers administered one or two antimicrobials were greater ($P \leq 0.05$) than MET and TEMP heifers administered one or two antimicrobials. In wk 3, 5, and 6 average ruminal temperature was affected ($P < 0.01$) by number of antimicrobials administered, as temperatures generally increased with increasing number of antimicrobials. During the final wk of the experiment there was an interaction ($P < 0.01$)

between management method and number of antimicrobials administered. Among heifers administered one antimicrobial, temperatures of CON heifers were 0.12°C higher ($P = 0.03$) than TEMP, and MET was intermediate. Among heifers administered two antimicrobials, temperatures of CON and MET heifers were 0.16°C higher ($P \leq 0.04$) than TEMP. However, among heifers administered three antimicrobials, temperatures of MET heifers were 0.17°C lower ($P = 0.02$) than TEMP.

Bronchoalveolar Lavage Samples

Prevalence of *A. pyogenes* was minimal (n = 6 isolates); therefore, results are not presented for this microorganism. In BAL samples obtained from heifers classified as clinically healthy, a greater ($P = 0.04$) percentage of TEMP samples contained zero pathogenic species compared to MET (Figure 2.6). Percent of samples containing one, two, or three pathogenic species was not affected ($P \geq 0.37$) by management method. There was a tendency ($P = 0.06$) for BAL samples of clinically healthy CON heifers to contain *M. haemolytica* 22% more often than TEMP (Figure 2.7). There were no differences ($P \geq 0.16$) due to management method in percent of samples containing *P. multocida*, *H. somni*, or *Mycoplasma* spp in heifers classified as clinically healthy. In BAL samples obtained from heifers at the time of first antimicrobial administration, which includes the metaphylactic dose in MET heifers, there was a tendency ($P = 0.06$) for samples from MET heifers to contain zero pathogenic species 26% more often than CON (Figure 2.8). There was also a tendency ($P = 0.10$) for samples from CON heifers to contain three pathogenic species 20% more often than TEMP. Samples obtained from CON heifers contained *H. somni* 27% more often ($P = 0.03$) than BAL samples obtained

from MET and TEMP heifers at the time of first antimicrobial administration (Figure 2.9). No other differences in number of pathogenic species present were observed ($P \geq 0.12$). In samples obtained at the time of second antimicrobial administration, no differences ($P \geq 0.53$) in management method were observed in percent of samples containing zero, one, or two pathogenic species (Figure 2.10). There were also no differences ($P \geq 0.45$) in percent of samples containing *P. multocida*, *M. haemolytica*, *H. somni*, or *Mycoplasma* spp. at the time of second antimicrobial administration (Figure 2.11).

DISCUSSION

Various forms of body temperature monitoring have been explored in cattle, including tympanic (Davis et al., 2003; Hahn et al., 1990), subdermal (Al-Haidary et al., 2001), and ruminal (AlZahal et al., 2008; Bewley et al., 2008; Rose-Dye et al., 2011). Ruminal temperature monitoring has potential to be an ideal method of remote body temperature monitoring as it is non-invasive and permanent.

Rose-Dye et al. (2011) used ruminal temperature monitoring in steers challenged with BVDV, *Mannheimia haemolytica*, or both, and observed greater temperatures in steers challenged with BRD pathogens compared to non-challenged control steers. After 4 h, ruminal temperatures of steers challenged with *M. haemolytica* had increased to levels greater than that of steers not challenged with *M. haemolytica*, indicating the temperature response to bacterial lung infection occurs rapidly (Rose-Dye et al., 2011). Theoretically, use of continuous ruminal temperature monitoring has the potential to detect illness quickly following the onset of infection. Increased temperatures are also

associated with lower ADG in newly received feedlot calves (Sims et al., 2007). There is, however, no published research using ruminal temperature monitoring to be used as a diagnostic tool for identification of BRD in cattle.

It is widely accepted that BRD has a negative impact on performance of feedlot cattle and a large number of cases go undetected as determined by lung lesions at harvest. In this experiment a greater number of calves received treatment for BRD as the result of ruminal temperature monitoring compared to visual observation alone. An increased frequency of treatments may have thus reduced severity of BRD in the TEMP heifers, resulting in the heavier BW and numerical improvements in ADG and G:F over CON. Heifers generally performed satisfactorily during the 56-d receiving phase. Gains were diminished during the period from d 42 to 56, as the first lot of heifers experienced high environmental temperatures during this time. Heifers either lost BW or gained very little, resulting in poor mean ADG, intake, and G:F during the final 14 d of the experiment.

Use of metaphylactic antimicrobial treatment and use of remote ruminal temperature monitoring both improved performance of newly received feedlot heifers during a 56-d receiving phase. Heifers managed under the MET method exhibited improved ADG and G:F, while heifers managed under the TEMP method exhibited greater BW at the end of the receiving phase compared to CON. Daniels et al. (2000) demonstrated that calves receiving a metaphylactic antimicrobial treatment for BRD gained more per d than those that did not during the first 21 d after arrival. Additionally, Booker et al. (2007) observed that calves receiving tulathromycin on arrival had improved ADG compared to calves receiving other metaphylactic antimicrobials. The improvements observed in performance of MET heifers may be attributed to improved

calf health. It is also likely that the greater BW observed in TEMP heifers may have come as a result of reduced BRD severity, as these calves were treated for BRD at a greater frequency compared to calves exposed to CON the method, and total number of antimicrobials administered was not different from the group administered metaphylaxis.

When comparing performance of calves based on management method and frequency of treatment for BRD, use of ruminal temperature monitoring resulted in improved performance. Among CON and MET heifers, BW and ADG generally decreased as the number of antimicrobials administered increased. Other researchers have also observed diminished performance as frequency of treatment for BRD increases (Gardner et al., 1999; Montgomery et al., 2009; Holland et al., 2010). Response to increasing number of BRD treatments did not necessarily follow this pattern in heifers managed with the TEMP method. Performance was similar among heifers that were never treated for BRD and those receiving one and two antimicrobials. It should also be noted that overall ADG and final BW of TEMP heifers identified with BRD zero, one and two antimicrobials were similar to performance of CON and MET heifers that were never identified with BRD. This may indicate that ruminal temperature monitoring successfully identified calves in the initial stages of BRD, thereby reducing the detrimental effects of the disease on performance. However, when considering the total number of antimicrobials administered, TEMP heifers that received three treatments for BRD did not perform as well as other TEMP heifers.

Temperature of cattle has been shown to decrease in response to metaphylaxis. Godinho et al. (2005) determined that rectal temperatures of calves administered tulathromycin remained lower than temperatures of calves administered saline for up to

nine days after injection following challenge with *Mycoplasma bovis*. Temperatures of all calves in the present study appear to have been elevated during the first wk of the experiment, as evidenced by the rapid decline in temperature during wk 2. This decline was most pronounced in MET heifers, likely a response to antimicrobial treatment. While metaphylaxis reduced temperatures during wk 1 and 2 compared to CON, it is notable that temperature monitoring reduced temperatures as well in wk 2 compared to CON. After wk 2, the response to metaphylaxis was no longer evident, as temperatures of MET heifers began to increase in wk 3. This coincides with the maximum recommended post-metaphylactic interval of 14 d for tulathromycin (Apley, 2006). By wk 5 and 6, average daily temperatures of MET heifers were greater than temperatures of TEMP heifers. Very few MET heifers received a second and third antimicrobial, as most of these calves did not show visual signs of BRD. However, it is possible that there was a greater level of subclinical disease in MET heifers at this time, as indicated by lower ruminal temperatures of TEMP heifers during wk 5 and 6. Many of the TEMP heifers were not exhibiting clinical signs of BRD at the time of antimicrobial administration; therefore, it is possible that temperature monitoring detected subclinical disease in these heifers, resulting in lower average daily ruminal temperatures compared to MET at wk 5 and 6.

When examining temperatures of calves based on management method and frequency of treatment for BRD, CON and MET heifers identified with BRD twice generally had greater temperatures compared to heifers identified with BRD once, which generally had greater temperatures compared to heifers never identified with BRD. However, oftentimes temperatures of TEMP heifers were not different in those identified

with BRD compared to those never identified. Additionally, temperatures of TEMP heifers identified with BRD zero, once, or twice were generally lower than their CON and MET counterparts. This may again indicate that temperature monitoring identified more cases of subclinical disease, resulting in lower temperatures in TEMP heifers compared to CON and MET.

Results from BAL samples indicate that fewer potential pathogenic species were present in the lungs of clinically healthy TEMP heifers, as approximately 40% of samples contained zero pathogenic species. While not statistically different, a decreasing percentage of samples from TEMP heifers contained one or two species. This is in contrast to BAL samples of clinically healthy MET heifers, of which 50% contained one potentially pathogenic specie. Upon examining the species isolated from samples from clinically healthy heifers, approximately 70% of samples from MET heifers contained *Mycoplasma* spp. It is important to note that *Mycoplasma* spp were not speciated, so it cannot be assumed that all 70% of MET samples contained *M. bovis*. However, it is interesting that even in calves administered metaphylaxis, *Mycoplasma* spp were evident in the BAL samples of clinically healthy calves. Samples from clinically healthy CON heifers tended to contain *M. haemolytica* more frequently than TEMP, further indicating that temperature monitoring potentially decreased incidence of subclinical disease.

For samples obtained at the time of first antimicrobial administration MET heifers were not necessarily exhibiting clinical signs of BRD, as these samples were obtained at the time of metaphylaxis. This explains the tendency for samples from MET heifers to contain zero pathogenic species more frequently than CON. The tendency for fewer samples from TEMP heifers at the time of first treatment to contain three pathogenic

species compared to CON agrees with the possibility that temperature monitoring aided in detection of subclinical BRD. Heifers pulled using the CON method were exhibiting visual signs of BRD, while those pulled using the TEMP method were not usually visually identified with BRD.

A potential explanation for the favorable results observed in TEMP heifers is the possibility that not all TEMP heifers treated for BRD were in fact suffering from the disease. This could have then led to the response that indicated performance of TEMP heifers treated once or twice was similar to that of clinically healthy CON, MET, and TEMP heifers. However, it should be noted that no heifer pulled based on ruminal temperature was treated with an antimicrobial if rectal temperature was not at least 40°C. This threshold is commonly used as an indicator of need for antimicrobial therapy (Pinchak et al., 2004; Richeson et al., 2009; White et al., 2009), although others have adopted even lower temperature thresholds (Duff et al., 2000; Montgomery et al., 2009). Therefore, it is unlikely that treated TEMP heifers were free of pathogens at the time of BRD treatment.

Performance of TEMP heifers administered three antimicrobials was reduced, indicating that treated TEMP heifers were affected by some level of disease. The percentage of BAL samples containing zero pathogenic species at the time of first treatment was numerically greatest in CON heifers which were visually identified with BRD, followed by TEMP heifers which were treated if rectal temperature was at least 40°C, which were then followed by MET heifers, which were administered their first antimicrobial regardless of visual signs or rectal temperature. This may provide evidence that treated TEMP heifers were experiencing some level of BRD, although severity may

not have been as great as that of CON heifers. Assuming the possibility that some treated heifers were not clinically ill, it is still notable that performance was spared through use of temperature monitoring, which supports the theory that temperature monitoring identified subclinical BRD in these calves.

Traditional BRD assessment methods are not sufficient to identify cases of subclinical BRD (Wittum et al., 1996), as cattle possess a unique ability to mask signs of illness, making it difficult even for experienced individuals to identify subclinical BRD (Edwards, 2010). Remote ruminal temperature monitoring has great potential to aid in detection of subclinical cases of BRD. Additional research is needed to more accurately determine how temperature changes in response to onset of performance reducing BRD, so that ruminal temperature monitoring may be used efficiently in terms of labor and cost.

LITERATURE CITED

Al-Haidary, A., D. E. Spiers, G. E. Rottinghaus, G. B. Garner, and M. R. Ekkersieck. 2001. Thermoregulatory ability of beef heifers following intake of endophyte-infected tall fescue during controlled heat challenge. J. Anim. Sci. 79:1780-1788.

AlZahal, O., E. Kebreab, J. France, M. Froetschel, and B. W. McBride. 2008. Ruminal temperature may aid in the detection of subacute ruminal acidosis. J. Dairy Sci. 81:202-207.

Apley, M. 2006. Bovine respiratory disease: Pathogenesis, clinical signs, and treatment in lightweight calves. Vet. Clin. Food Anim. 22:399-411.

Bewley, J. M., M. E. Einstein, M. W. Grott, and M. M. Schutz. 2008. Comparison of reticular and rectal core body temperatures in lactating dairy cows. J. Dairy Sci. 91:4661-4672.

Booker, C. W., S. M. Abutarbush, O. C. Schunicht, G. K. Jim, T. Perrett, B. K. Wildman, P. T. Guichon, T. J. Pittman, C. Jones, C. M. Pollock. 2007. Evaluation of the efficacy of tulathromycin as a metaphylactic antimicrobial in feedlot calves. Vet. Therap. 8:183-200.

Bryant, L. K., L. J. Perino, D. Griffin, A. R. Doster, and T. E. Wittum. 1999. A method for recording pulmonary lesions of beef calves at slaughter, and the association of lesions with average daily gain. Bov. Pract. 33:163-173.

Buhman, M. J., L. J. Perino, M. L. Galyean, T. E. Wittum, T. H. Montgomery, and R. S. Wingle. 2000. Association between changes in eating and drinking behaviors

and respiratory tract disease in newly arrived calves at a feedlot. Am. J. Vet. Res. 61:1163-1168.

Chen, L., D. B. Paulsen, D. W. Scruggs, M. M. Banes, B. Y. Reeks, and M. L. Lawrence. 2003. Alteration of DNA adenine methylase (Dam) activity in *Pasteurella multocida* causes increased spontaneous mutation frequency and attenuation in mice. Microbiology. 149:2283-2290.

Chirase, N. K, and Greene, L. W. 2000. Influence of oral natural interferon-alpha on performance and rectal temperature of newly received beef steers. Western Section Am. Soc. Anim. Sci. Proc. 51:411-414.

Daniels, T. K., J. G. P. Bowman, B. F. Sowell, M. E. Branine, and M. E. Hubbert. 2000. Effects of metaphylactic antibiotics on behavior of feedlot calves. Prof. Anim. Sci. 16:247-253.

Davis, M. S., T. L. Mader, S. M. Holt, and A. M. Parkhurst. 2003. Strategies to reduce feedlot cattle heat stress: Effects on tympanic temperature. J. Anim. Sci. 81:649-661.

Duff, G. C., D. A. Walker, K. J. Malcolm-Callis, M. W. Wiseman, and D. M. Hallford. 2000. Effects of preshipping vs. arrival medication with tilmicosin phosphate and feeding chlortetracycline on health and performance of newly received beef cattle. J. Anim. Sci. 78:267-274.

Edwards, T. A. 2010. Control methods for bovine respiratory disease for feedlot cattle. Vet. Clin. Food Anim. 26:273-284.

Fulton, R. W., B. J. Book, D. L. Step, A. W. Confer, J. T. Saliki, M. E. Payton, L. J. Burge, R. D. Welsh, K. S. Blood. 2002. Evaluation of health status of calves and

the impact on feedlot performance: assessment of a retained ownership program for postweaning calves. Can. J. Vet. Res. 66:173-180.

Gardner, B. A., H. G. Dolezal, L. K. Bryant, F. N. Owens, and R. A. Smith. 1999. Health of finishing steers: effects on performance, carcass traits, and meat tenderness. J. Anim. Sci. 77:3168-3175.

Godinho, K. S., A. Rae, G. D. Windsor, N. Tilt, T. G. Rowan, and S. J. Sunderland. 2005. Efficacy of tulathromycin in the treatment of bovine respiratory disease associated with induced *Mycoplasma bovis* infections in young dairy calves. Vet. Ther. 6:96-112.

Griffin, D. 1996. Etiology, pathogenesis, and clinical signs of bovine respiratory disease. In: R. Smith (Ed.) Review of Bovine Respiratory Disease – Schering-Plough Animal Health. pp 6-11. Veterinary Learning Systems, Trenton, NJ.

Griffin, D., M. M. Chengappa, J. Kuszak, and D. S. McVey. 2010. Bacterial pathogens of the bovine respiratory disease complex. Vet. Clin. Food Anim. 26:381-394.

Hahn, G. L., R. A. Eigenberg, J. A. Nienaber, and E. T. Littledike. 1990. Measuring physiological responses of animals to environmental stressors using a microcomputer-based portable datalogger. J. Anim. Sci. 68:2658-2665.

Holland, B. P., L. O. Burciaga-Robles, D. L. VanOverbeke, J. N. Shook, D. L. Step, C. J. Richards, and C. R. Krehbiel. 2010. Effect of bovine respiratory disease during preconditioning on subsequent feedlot performance, carcass characteristics, and beef attributes. J. Anim. Sci. 88:2486-2499.

Katsuda, K., M. Kamiyama, M. Kohmoto, K. Kawashima, H. Tsunemitsu, and M. Eguchi. 2008. Sterotyping of *Mannheimia haemolytica* isolates from bovine pneumonia: 1987-2006. Vet. J. 178:146-148.

Montgomery, S. P., J. J. Sindt, M. A. Greenquist, W. F. Miller, J. N. Pike, E. R. Loe, M. J. Sulpizio, and J. S. Drouillard. 2009. Plasma metabolites of receiving heifers and the relationship between apparent bovine respiratory disease, body weight gain, and carcass characteristics. J. Anim. Sci. 87:328-333.

National Agricultural Statistics Service. 2006. Cattle death loss. http://usda.mannlib.cornell.edu/usda/current/CattDeath/CattDeath-05-05-2006.pdf Accessed March 27, 2010.

Panciera, R. J., and A. W. Confer. 2010. Pathogenesis and pathology of bovine pneumonia. Vet. Clin. Food Anim. 26:191-214.

Pinchak, W. E., D. R. Tolleson, M. McCloy, L. J. Hunt, R. J. Gill, R. J. Ansley, and S. J. Bevers. 2004. Morbidity effects on productivity and profitability of stocker cattle grazing in the Southern Plains. J. Anim. Sci. 82:2773-2779.

Reinhardt, C. D., W. D. Busby, and L. R. Corah. 2009. Relationship of various incoming cattle traits with feedlot performance and carcass traits. J. Anim. Sci. 87:3030-3042.

Richeson, J. T., E. B. Kegley, M. S. Gadberry, P. A. Beck, J. G. Powell, and C. A. Jones. 2009. Effects of on-arrival versus delayed clostridial or modified live respiratory vaccinations on health, performance, bovine viral diarrhea virus type I titers, and stress and immune measures of newly received beef calves. J. Anim. Sci. 87:2409-2418.

Ridpath, J. 2010. The contribution of infections with bovine viral diarrhea viruses to bovine respiratory disease. Vet. Clin. Food Anim. 26:335-348.

Rose-Dye, T. K., L. O. Burciaga-Robles, C. R. Krehbiel, D. L. Step, R. W. Fulton, A. W. Confer, and C. J. Richards. 2011. Rumen temperature change monitored with remote rumen temperature boluses after challenges with bovine viral diarrhea virus and *Mannheimia haemolytica*. J. Anim. Sci. 89:1193-1200.

Schneider, M. J., R. G. Tait, Jr., W. D. Busby, and J. M. Reecy. 2009. An evaluation of bovine respiratory disease complex in feedlot cattle: Impact on performance and carcass traits using treatment records and lung lesion scores. J. Anim. Sci. 87:1821-1827.

Sims, L. E., T. K. Dye-Rose, C. L. Goad, B. P. Holland, L. O. Burciaga-Robles, D. L. Step, C. R. Krehbiel, and C. J. Richards. 2009. Use of rumen temperature for health monitoring in cattle. J. Anim. Sci. 87(E-Suppl 2): 120. (Abstr.)

Thompson, P. N., A. Stone, and W. A. Schultheiss. 2006. Use of treatment records and lung lesion scoring to estimate the effect of respiratory disease on growth during early and late finishing periods in South African feedlot cattle. J. Anim. Sci. 84:488-498.

White, B. J., D. Blasi, L. C. Vogel, and M. Epp. 2009. Associations of beef calf wellness and body weight gain with internal location in a truck during transportation. J. Anim. Sci. 87:4143-4150.

Wittum, T. E., N. E. Woollen, L. J. Perino, and E. T. Littledike. 1996. Relationships among treatment for respiratory tract disease, pulmonary lesions evident at

slaughter, and rate of weight gain in feedlot cattle. J. Am. Vet. Med. Assoc. 209:814-818.

Table 2.1. Ingredient and nutrient composition of receiving diet

Item	
Ingredient, %	
Dry rolled corn	35.5
Dried distillers grains	18.0
Ground prairie hay	19.0
Ground alfalfa hay	18.0
Liquid supplement[1]	3.5
Dry supplement[2]	6.0
Nutrient	
DM, %	87.44
NE_m, Mcal/kg	1.57
NE_g, Mcal/kg	0.97
CP, %	14.5
ADF, %	18.9
NDF, %	32.6
Ca, %	0.65
P, %	0.34

[1]Synergy 19/14 (Westway Feed Products, New Orleans, LA).

[2]Pelleted supplement contained the following (DM basis): 60.14% ground corn, 16.67% wheat middlings, 15.00% limestone, 1.67% urea, 4.16% salt, 1.67% magnesium oxide, 0.04% manganous oxide, 0.33% zinc sulfate, 0.07% vitamin A (30,000 IU/g), 0.04% vitamin E (50%), and 0.21% Rumensin 80 (Elanco Animal Health, Indianapolis, IN).

Table 2.2. Frequency of times pulled and times treated for heifers managed with three bovine respiratory disease (BRD) management methods

	Management method[1]				
Item	CON	MET	TEMP	SEM	*P*-Value
Pulls					
n	127	77	532		
Times per heifer	1.13[a]	0.68[a]	4.51[b]	0.48	<0.01
Treatments for BRD following a pull[2]					
n	67	31	174		
Times per heifer	0.59[b]	0.27[a]	1.47[c]	0.22	<0.01
% of times pulled	65.21	36.11	40.86	9.09	0.11
Rectal temperature, °C	40.62[b]	40.54[ab]	40.41[a]	0.09	0.01
Number of antimicrobials administered[3]					
n	67	148	174		
Times per heifer	0.59[a]	1.27[b]	1.47[b]	0.22	<0.01
Dead, n	3	0	3		

[1]BRD Management method: CON = pulled based on visual signs of BRD, MET = administered a metaphylactic dose of tulathromycin at processing and subsequently pulled based on visual signs of BRD, TEMP = pulled based on visual signs of BRD or elevated ruminal temperature.
[2]Does not include metaphylactic dose administered to MET heifers.
[3]Includes metaphylactic dose administered to MET heifers.
[abc]Means within a row without a common superscript differ ($P \leq 0.05$).

Table 2.3. Receiving phase performance for heifers managed with three bovine respiratory disease (BRD) management methods

	Management Method[1]				
Item	CON	MET	TEMP	SEM	*P*-Value
BW, kg					
d 0	244.0	243.0	245.2	13.9	0.29
d 14	262.8	267.7	267.2	12.7	0.31
d 28	280.6[a]	287.9[b]	284.4[ab]	12.7	0.04
d 42	305.0	308.7	308.8	14.2	0.15
d 56	312.2[a]	316.1[ab]	317.4[b]	13.6	0.05
ADG, kg					
d 0 – 14	1.07	1.68	1.33	0.38	0.06
d 14 – 28	1.25	1.45	1.19	0.25	0.36
d 28 – 42	1.74	1.48	1.73	0.27	0.24
d 42 – 56	0.51	0.54	0.62	0.22	0.65
d 0 – 56	1.15[a]	1.27[b]	1.22[ab]	0.04	<0.01
DMI, kg/d					
d 0 – 14	4.79	5.01	4.89	0.67	0.31
d 14 – 28	6.63	6.91	6.85	0.33	0.38
d 28 – 42	7.77	7.75	7.57	0.33	0.73
d 42 – 56	8.08	8.01	7.83	0.35	0.65
d 0 – 56	6.80	6.94	6.79	0.36	0.54
G:F					
d 0 – 14	0.264	0.372	0.307	0.095	0.10
d 14 – 28	0.192	0.206	0.174	0.032	0.56
d 28 – 42	0.222	0.190	0.229	0.030	0.17
d 42 – 56	0.065	0.069	0.080	0.029	0.55
d 0 – 56	0.175[a]	0.190[b]	0.184[ab]	0.009	0.03

[1]BRD Management Method: CON = pulled based on visual signs of BRD, MET = administered a metaphylactic dose of tulathromycin at processing and subsequently pulled based on visual signs of BRD, TEMP = pulled based on visual signs of BRD or elevated ruminal temperature.
[ab]Means within a row without a common superscript differ ($P \leq 0.05$).

Table 2.4. Receiving phase performance for heifers managed with three bovine respiratory disease (BRD) management methods and identified with and treated for BRD zero, one, or two times

	Management Method[1]												
	CON			MET			TEMP				*P*-Values[2]		
Item	0	1	2	0	1	2	0	1	2	SEM	M	T	M×T
BW, kg													
d 0	246.3	241.0	243.3	243.2	240.3	243.2	246.6	245.9	244.7	14.9	0.58	0.60	0.94
d 14[3,4]	270.3	255.1	248.4	269.6	259.3	259.4	267.6	268.3	269.6	14.1	0.02	0.01	0.12
d 28[3,4]	286.3	276.6	258.1	290.8	276.4	274.3	289.9	285.8	286.5	14.4	<0.01	<0.01	0.25
d 42	312.4^{c}	301.6^{bc}	273.6^{a}	311.8^{c}	300.3^{bc}	289.4^{ab}	311.6^{c}	314.0^{c}	309.6^{c}	15.7	<0.01	<0.01	0.04
d 56	320.5^{d}	307.0^{bc}	280.9^{a}	319.0^{cd}	309.1^{bcd}	299.1^{ab}	320.0^{cd}	322.0^{d}	320.2^{d}	15.4	<0.01	<0.01	0.02
ADG, kg													
d 0-14	1.39^{bc}	0.83^{b}	0.15^{a}	1.74^{c}	1.40^{bc}	1.48^{bc}	1.32^{bc}	1.29^{bc}	1.57^{c}	0.54	0.01	0.03	0.02
d 14-28	1.21	1.43	0.58	1.51	1.25	1.10	1.38	1.29	1.17	0.38	0.52	0.06	0.33
d 28-42[5]	1.85	1.79	1.12	1.50	1.69	1.06	1.56	1.99	1.69	0.37	0.31	0.02	0.30
d 42-56	0.57	0.40	0.51	0.51	0.63	0.69	0.59	0.57	0.76	0.34	0.59	0.76	0.87
d 0-56	1.24^{bc}	1.14^{b}	0.61^{a}	1.30^{c}	1.22^{bc}	1.06^{b}	1.24^{bc}	1.28^{c}	1.27^{bc}	0.12	<0.01	<0.01	<0.01

[1]BRD Management method: CON = pulled based on visual signs of BRD, MET = administered a metaphylactic dose of tulathromycin at processing and subsequently pulled based on visual signs of BRD, TEMP = pulled based on visual signs of BRD or elevated ruminal temperature.
[2]Comparisons: M = management method, T = number of times identified with and treated for BRD, M×T = interaction between M and T.
[3]M effect: CON < MET ($P \leq 0.05$).
[4]T effect: 0 > 1, 2 ($P \leq 0.05$).
[5]T effect: 1 < 2 ($P \leq 0.05$).
[abcd]Means within a row without a common superscript differ ($P \leq 0.05$).

Table 2.5. Receiving phase performance for heifers managed with three bovine respiratory disease (BRD) management methods and administered one, two, or three antimicrobials

	Management Method[1]											
	CON		MET			TEMP				*P*-Values[2]		
Item	1	2	1[3]	2	3	1	2	3	SEM	M	A	M×A
BW, kg												
d 0	240.5	243.4	243.1	240.4	243.4	245.8	244.6	243.7	15.4	0.65	0.99	0.86
d 14[4]	257.4	248.8	269.2	260.3	260.9	267.5	269.8	263.8	12.8	0.02	0.24	0.51
d 28[4,6]	276.6	259.6	290.4	277.6	276.0	285.4	286.5	276.3	14.9	<0.01	<0.01	0.24
d 42[4,6]	301.5	274.8	311.4	301.3	290.9	313.6	309.5	297.7	15.9	<0.01	<0.01	0.18
d 56[5,6]	306.0	281.1	318.6	309.9	300.3	321.3	320.2	306.0	14.4	<0.01	<0.01	0.21
ADG, kg												
d 0-14	0.90[b]	0.18[a]	1.73[c]	1.43[bc]	1.53[bc]	1.25[bc]	1.61[bc]	1.25[bc]	0.49	0.03	0.25	0.03
d 14-28[6]	1.47	0.63	1.51	1.25	1.12	1.29	1.18	0.90	0.42	0.43	<0.01	0.44
d 28-42[7]	1.76	1.12	1.50	1.69	1.07	1.97	1.70	1.53	0.35	0.10	<0.01	0.18
d 42-56	0.40	0.52	0.51	0.62	0.67	0.57	0.74	0.60	0.32	0.61	0.56	0.96
d 0-56	1.13[bc]	0.60[a]	1.30[c]	1.22[bc]	1.07[bc]	1.28[c]	1.27[c]	1.05[b]	0.14	<0.01	<0.01	<0.01

[1]BRD Management method: CON = pulled based on visual signs of BRD, MET = administered a metaphylactic dose of tulathromycin at processing and subsequently pulled based on visual signs of BRD, TEMP = pulled based on visual signs of BRD or elevated ruminal temperature.
[2]Comparisons: M = management method, A = number of antimicrobials administered for BRD, M×A = interaction between M and A.
[3]First antimicrobial administered for MET method was a metaphylactic dose of tulathromycin.
[4]M effect: CON < MET, TEMP ($P \leq 0.05$).
[5]M effect: CON < TEMP ($P \leq 0.05$).
[6]A effect: 1 > 2, 3 ($P \leq 0.05$).
[7]A effect: 1 > 3 ($P \leq 0.05$).
[abc]Means within a row without a common superscript differ ($P \leq 0.05$).

Table 2.6. Maximum and average daily temperature for heifers managed with three bovine respiratory disease (BRD) management methods and identified with and treated for BRD zero, one, or two times

	Management method[1]												
	CON			MET			TEMP				*P*-Value[2]		
Item	0	1	2	0	1	2	0	1	2	SEM	M	T	M×T
Maximum daily temperature, °C													
Wk 1[3,8]	40.53	40.76	40.86	40.35	40.59	40.82	40.32	40.53	40.74	0.19	0.05	<0.01	0.62
Wk 2	40.37^{bc}	40.57^{d}	40.86^{e}	40.18^{a}	40.61^{d}	40.46^{cd}	40.23^{ab}	40.20^{a}	40.36^{bc}	0.08	<0.01	<0.01	<0.01
Wk 3	40.46^{cde}	40.51^{de}	40.58^{ef}	40.35^{abc}	40.63^{ef}	40.75^{f}	40.26^{ab}	40.21^{a}	40.35^{bcd}	0.17	<0.01	<0.01	<0.01
Wk 4[9]	40.46	40.37	40.48	40.44	40.55	40.58	40.35	40.26	40.43	0.29	0.08	0.05	0.11
Wk 5	40.27^{bcd}	40.17^{ab}	40.35^{cde}	40.30^{cd}	40.41^{de}	40.44^{e}	40.14^{ab}	40.07^{a}	40.21^{bc}	0.07	<0.01	<0.01	0.02
Wk 6[4,10]	40.31	40.33	40.46	40.37	40.51	40.71	40.23	40.21	40.37	0.21	<0.01	<0.01	0.10
Wk 7	40.12^{abc}	40.23^{cde}	40.23^{cde}	40.18^{bcd}	40.31^{e}	40.38^{e}	40.07^{ab}	40.04^{a}	40.25^{de}	0.14	0.01	<0.01	0.02
Wk 8	40.06^{a}	40.17^{bc}	40.31^{cd}	40.17^{bc}	40.37^{d}	40.15^{abc}	40.01^{a}	40.02^{a}	40.09^{ab}	0.07	<0.01	<0.01	<0.01
Average daily temperature, °C													
Wk 1[5,8]	39.85	40.06	40.26	39.70	39.88	40.17	39.68	39.86	40.04	0.15	0.02	<0.01	0.66
Wk 2	39.62^{ab}	39.80^{c}	40.23^{d}	39.49^{a}	39.82^{c}	39.82^{c}	39.51^{a}	39.50^{a}	39.63^{b}	0.07	<0.01	<0.01	<0.01
Wk 3	39.67^{b}	39.77^{c}	39.98^{de}	39.62^{ab}	39.82^{cd}	40.00^{e}	39.52^{a}	39.53^{a}	39.63^{b}	0.14	<0.01	<0.01	<0.01
Wk 4[6,10]	39.68	39.65	39.78	39.68	39.68	39.84	39.58	39.52	39.65	0.13	0.01	<0.01	0.72
Wk 5[7,10]	39.62	39.56	39.69	39.64	39.71	39.78	39.51	39.49	39.57	0.06	<0.01	<0.01	0.08
Wk 6[7,10]	39.62	39.56	39.69	39.64	39.71	39.78	39.51	39.49	39.57	0.06	<0.01	<0.01	0.08
Wk 7	39.49^{abc}	39.60^{de}	39.52^{abcd}	39.53^{bcd}	39.59^{de}	39.69^{e}	39.44^{a}	39.45^{ab}	39.57^{cde}	0.05	0.02	<0.01	<0.01
Wk 8	39.44^{ab}	39.57^{cde}	39.66^{de}	39.55^{bcd}	39.68^{e}	39.56^{bcd}	39.42^{a}	39.45^{ab}	39.49^{abc}	0.06	<0.01	<0.01	<0.01

[1]BRD Management method: CON = pulled based on visual signs of BRD, MET = administered a metaphylactic dose of tulathromycin at processing and subsequently pulled based on visual signs of BRD, TEMP = pulled based on visual signs of BRD or elevated ruminal temperature.
[2]Comparisons: M = management method, T = number of times identified with and treated for BRD, M×T = interaction between M and T.
[3]M effect: CON > TEMP ($P \leq 0.05$).
[4]M effect: CON, TEMP < MET ($P \leq 0.05$).
[5]M effect: CON > MET, TEMP ($P \leq 0.05$).
[6]M effect: CON, MET > TEMP ($P \leq 0.05$).
[7]M effect: MET > TEMP ($P \leq 0.05$).
[8]T effect: 0 < 1 < 2 ($P \leq 0.05$).
[9]T effect: 1 < 2 ($P \leq 0.05$).
[10]T effect: 0, 1 < 2 ($P \leq 0.05$).
[abcdef]Means within a row without a common superscript differ ($P \leq 0.05$).

Table 2.7. Maximum and average daily temperature for heifers managed with three bovine respiratory disease (BRD) management methods and administered one, two, or three antimicrobials

	Management method[1]											
	CON		MET			TEMP				*P*-Value[2]		
Item	1	2	1[3]	2	3	1	2	3	SEM	M	A	M×A
Maximum daily temperature, °C												
Wk 1[4,6]	40.81	40.87	40.35	40.59	40.82	40.53	40.74	40.86	0.20	0.04	<0.01	0.10
Wk 2	40.56^{c}	40.86^{d}	40.18^{a}	40.61^{c}	40.46^{bc}	40.19^{a}	40.37^{b}	40.56^{c}	0.08	<0.01	<0.01	<0.01
Wk 3[5,6]	40.50	40.55	40.35	40.63	40.75	40.20	40.37	40.65	0.16	0.01	<0.01	0.07
Wk 4	40.40^{ab}	40.46^{b}	40.45^{b}	40.54^{bc}	40.57^{bc}	40.24^{a}	40.45^{b}	40.71^{c}	0.27	0.77	<0.01	<0.01
Wk 5	40.18^{ab}	40.35^{cde}	40.30^{bcd}	40.41^{de}	40.45^{e}	40.06^{a}	40.23^{bc}	40.51^{e}	0.08	0.14	<0.01	<0.01
Wk 6[6]	40.35	40.45	40.37	40.51	40.71	40.20	40.39	40.60	0.21	0.17	<0.01	0.76
Wk 7	40.24^{bc}	40.21^{bc}	40.17^{b}	40.30^{c}	40.38^{cd}	40.05^{a}	40.26^{bc}	40.50^{d}	0.14	0.78	<0.01	<0.01
Wk 8	40.17^{b}	40.28^{bc}	40.17^{b}	40.37^{c}	40.15^{ab}	40.02^{a}	40.11^{ab}	40.40^{c}	0.08	0.39	<0.01	<0.01
Average daily temperature, °C												
Wk 1	40.08^{c}	40.23^{d}	39.70^{a}	39.88^{bc}	40.18^{d}	39.87^{ab}	40.02^{c}	40.09^{cd}	0.18	0.02	<0.01	0.03
Wk 2	39.78^{c}	40.21^{d}	39.49^{a}	39.82^{c}	39.82^{c}	39.50^{a}	39.63^{b}	39.75^{c}	0.06	<0.01	<0.01	<0.01
Wk 3[5,6]	39.75	39.96	39.62	39.82	40.00	39.53	39.63	39.86	0.13	<0.01	<0.01	0.21
Wk 4	39.66^{b}	39.77^{cd}	39.68^{bc}	39.68^{bc}	39.84^{d}	39.52^{a}	39.66^{bc}	39.89^{d}	0.11	0.17	<0.01	<0.01
Wk 5[6]	39.56	39.69	39.63	39.72	39.78	39.49	39.58	39.78	0.07	0.12	<0.01	0.10
Wk 6[6]	39.65	39.68	39.67	39.71	39.95	39.56	39.67	39.82	0.08	0.07	<0.01	0.38
Wk 7	39.60^{bc}	39.51^{ab}	39.52^{ab}	39.60^{bc}	39.70^{cd}	39.46^{a}	39.57^{bc}	39.75^{d}	0.06	0.93	<0.01	<0.01
Wk 8	39.57^{bcd}	39.63^{cde}	39.55^{abc}	39.68^{de}	39.56^{abcd}	39.45^{a}	39.50^{ab}	39.73^{e}	0.05	0.35	<0.01	<0.01

[1]BRD Management method: CON = pulled based on visual signs of BRD, MET = administered a metaphylactic dose of tulathromycin at processing and subsequently pulled based on visual signs of BRD, TEMP = pulled based on visual signs of BRD or elevated ruminal temperature.
[2]Comparisons: M = management method, A = number of antimicrobials administered for BRD, M×A = interaction between M and A.
[3]First antimicrobial administered for MET method was a metaphylactic dose of tulathromycin.
[4]M effect: CON > MET ($P \leq 0.05$).
[5]M effect: CON, MET > TEMP ($P \leq 0.05$).
[6]A effect: 1 < 2 < 3 ($P \leq 0.05$).
[abcde]Means within a row without a common superscript differ ($P \leq 0.05$).

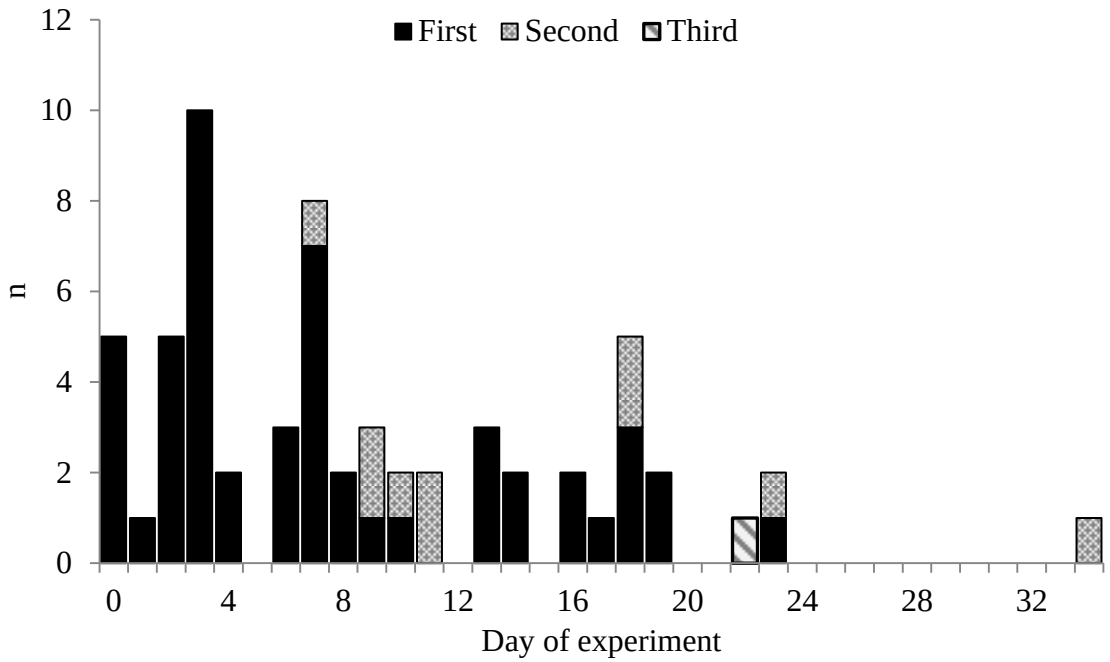

Figure 2.1. Timing distribution of treatment for bovine respiratory disease (BRD) in heifers pulled based on visual signs of BRD (CON).

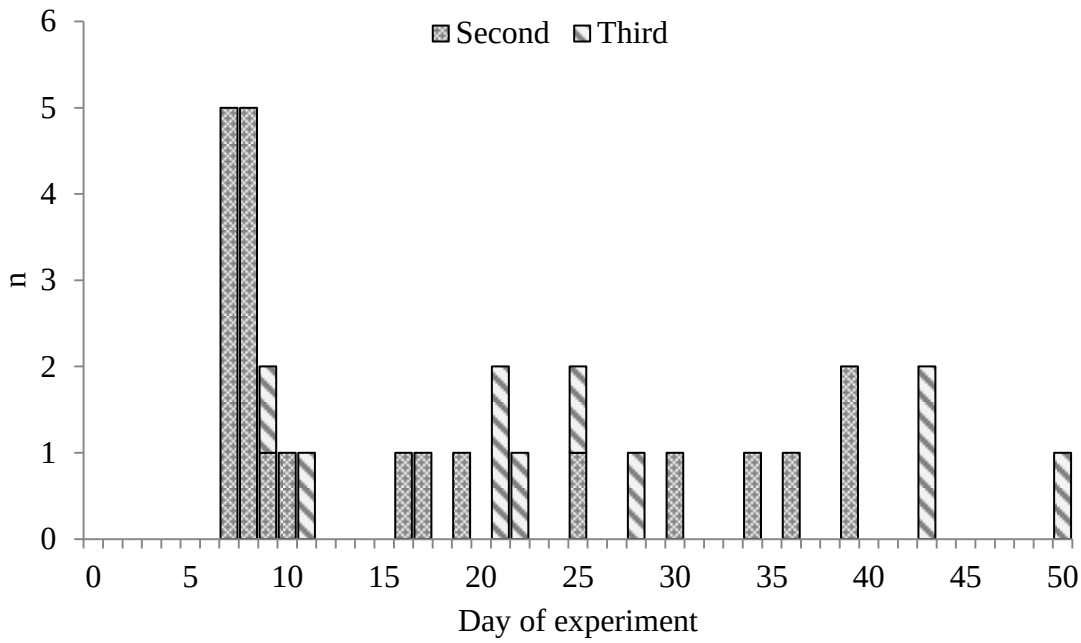

Figure 2.2. Timing distribution of treatment for bovine respiratory disease (BRD) in heifers after an administration of a metaphylactic dose of tulathromycin on d 0 and subsequently pulled based on visual signs of BRD (MET).

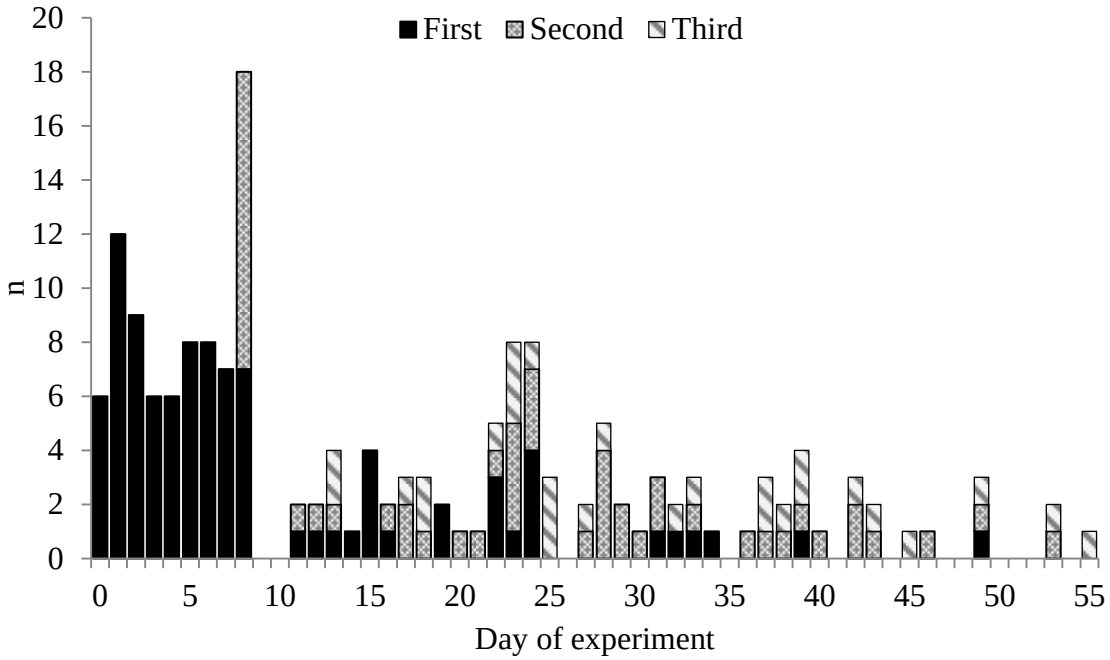

Figure 2.3. Timing distribution of treatment for bovine respiratory disease (BRD) in heifers pulled based on visual signs of BRD or elevated ruminal temperature (TEMP).

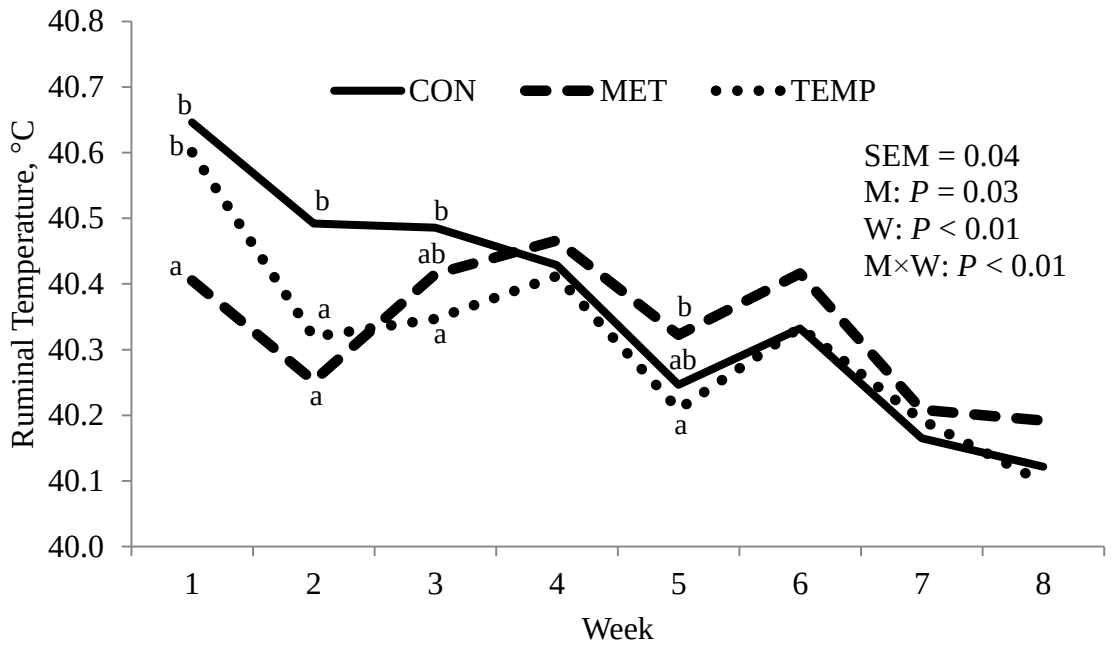

Figure 2.4. Maximum daily ruminal temperature of heifers managed with three bovine respiratory disease (BRD) management methods by week, °C. Management methods: CON, pulled based on visual signs of BRD; MET, administered a metaphylactic dose of tulathromycin at processing and subsequently pulled based on visual signs of BRD; TEMP, pulled based on visual signs of BRD or elevated ruminal temperature; n = 8 pens per method. Comparisons: M, effect of management method; W, effect of week; M×W, interaction of M and W. Means within a week without a common label differ ($P \leq 0.05$).

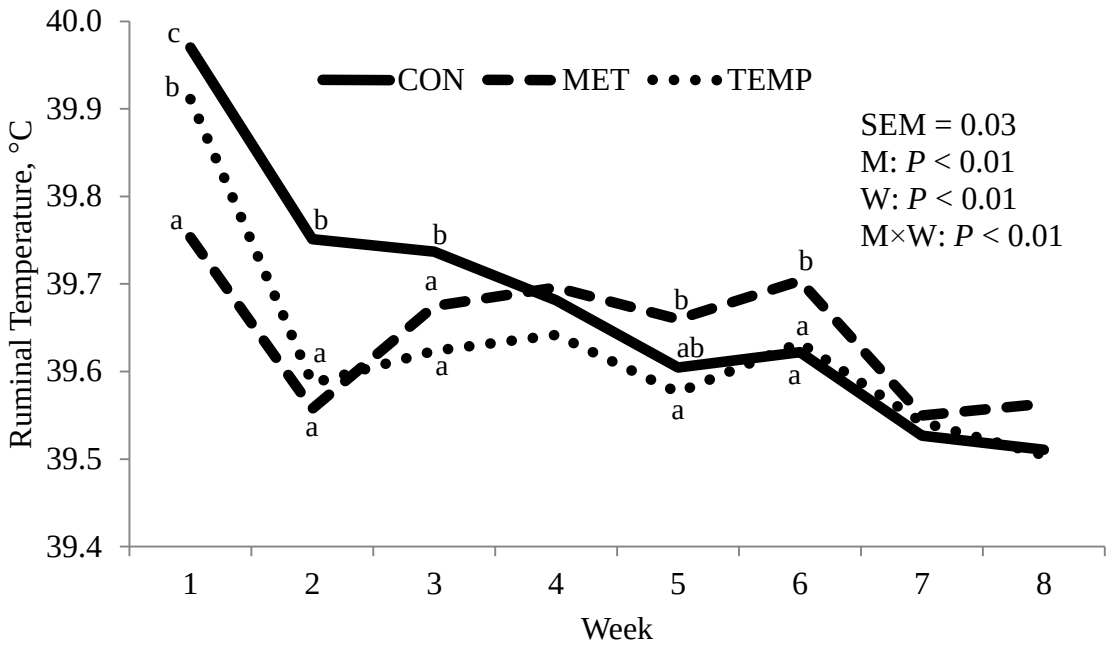

Figure 2.5. Average daily ruminal temperature of heifers managed with three bovine respiratory disease (BRD) management methods by week, °C. Management methods: CON, pulled based on visual signs of BRD; MET, administered a metaphylactic dose of tulathromycin at processing and subsequently pulled based on visual signs of BRD; TEMP, pulled based on visual signs of BRD or elevated ruminal temperature; n = 8 pens per method. Comparisons: M, effect of management method; W, effect of week; M×W, interaction of M and W. Means within a week without a common label differ ($P \leq 0.05$).

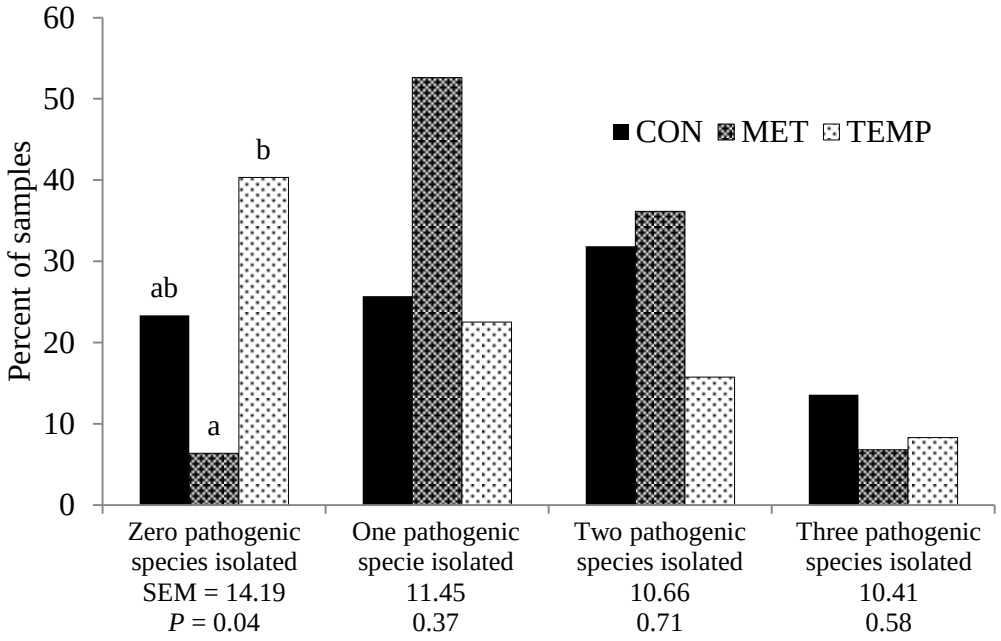

Figure 2.6. Number of species isolated in bronchoalveolar lavage samples from heifers managed with three bovine respiratory disease (BRD) management methods and classified as clinically healthy. Management methods: CON, pulled based on visual signs of BRD; MET, administered a metaphylactic dose of tulathromycin at processing and subsequently pulled based on visual signs of BRD; TEMP, pulled based on visual signs of BRD or elevated ruminal temperature. Number of observations: CON = 35, MET = 19, TEMP = 71. Means within an item without a common label differ ($P \leq 0.05$).

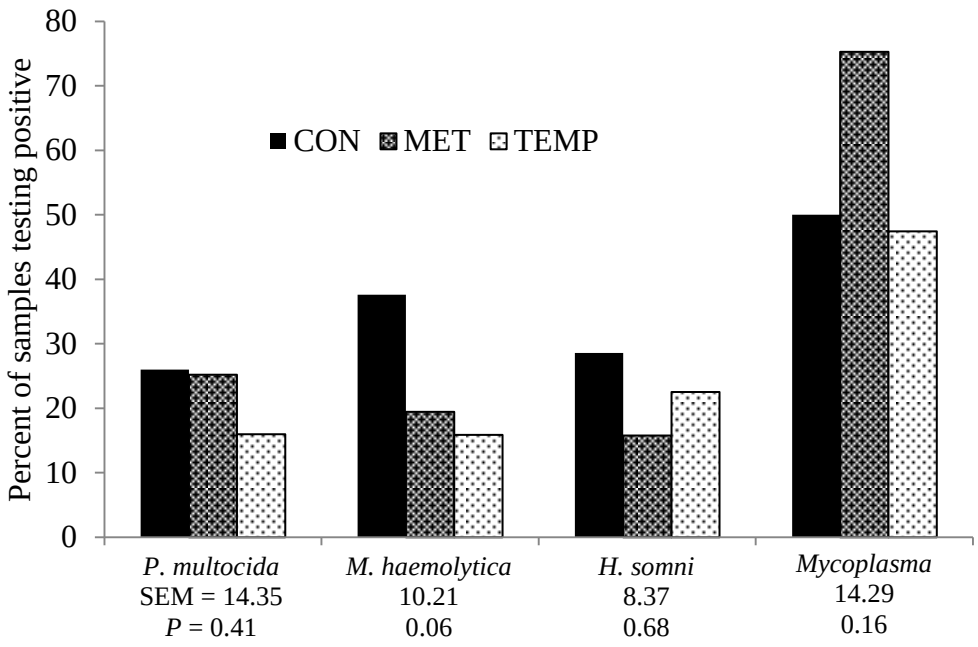

Figure 2.7. Percentage of bronchoalveolar lavage samples testing positive for pathogens related to bovine respiratory disease (BRD) in heifers managed with three BRD management methods and classified as clinically healthy. Management methods: CON, pulled based on visual signs of BRD; MET, administered a metaphylactic dose of tulathromycin at processing and subsequently pulled based on visual signs of BRD; TEMP, pulled based on visual signs of BRD or elevated ruminal temperature. Number of observations: CON = 35, MET = 19, TEMP = 71. Pathogens include *Pasteurella multocida*, *Mannheimia haemolytica*, *Histophilus somni*, and *Mycoplasma spp*.

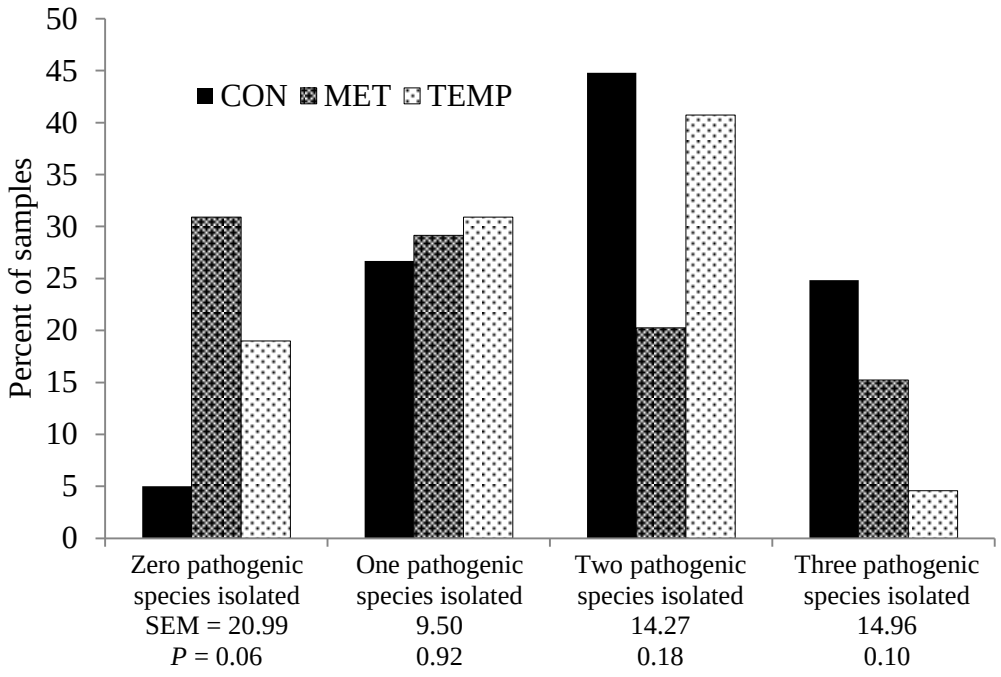

Figure 2.8. Number of species isolated in bronchoalveolar lavage samples from heifers managed with three bovine respiratory disease (BRD) management methods at the time of first antimicrobial administration. Management methods: CON, pulled based on visual signs of BRD; MET, administered a metaphylactic dose of tulathromycin at processing and subsequently pulled based on visual signs of BRD; TEMP, pulled based on visual signs of BRD or elevated ruminal temperature. Number of observations: CON = 26, MET = 24, TEMP = 48.

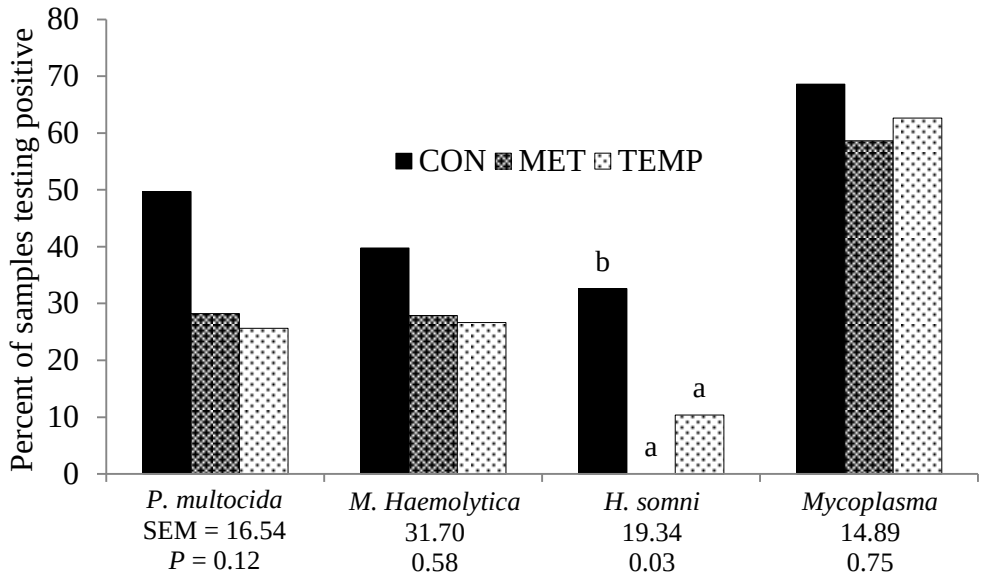

Figure 2.9. Percentage of bronchoalveolar lavage samples testing positive for pathogens related to bovine respiratory disease (BRD) in heifers managed with three BRD management methods at the time of first antimicrobial administration. Management methods: CON, pulled based on visual signs of BRD; MET, administered a metaphylactic dose of tulathromycin at processing and subsequently pulled based on visual signs of BRD; TEMP, pulled based on visual signs of BRD or elevated ruminal temperature. Number of observations: CON = 26, MET = 24, TEMP = 48. Pathogens include *Pasteurella multocida*, *Mannheimia haemolytica*, *Histophilus somni*, and *Mycoplasma spp*. Means within an item without a common label differ ($P \leq 0.05$).

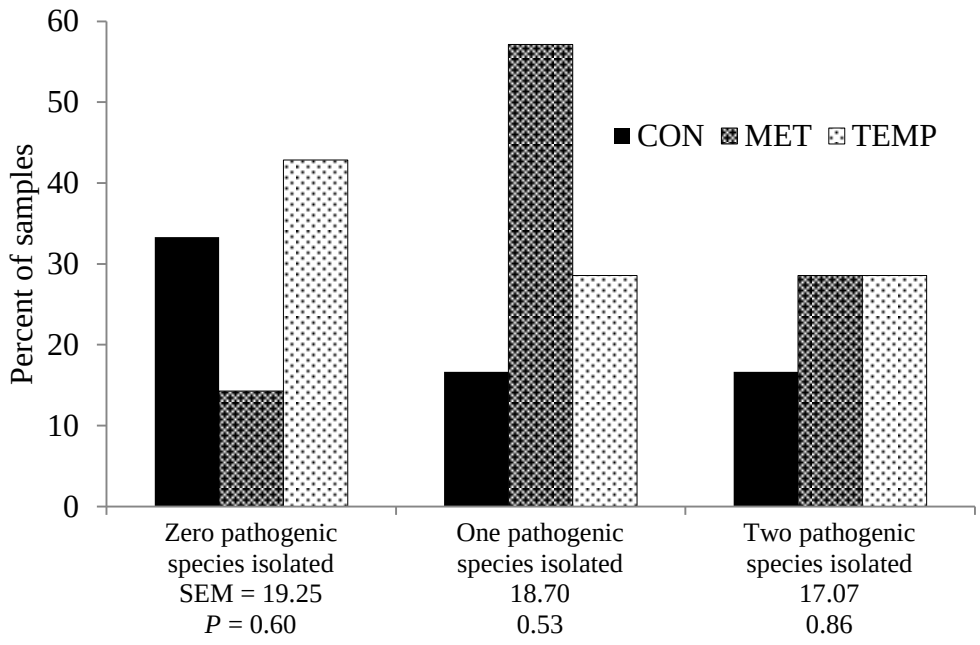

Figure 2.10. Number of species isolated in bronchoalveolar lavage samples from heifers managed with three bovine respiratory disease (BRD) management methods at the time of second antimicrobial administration. Management methods: CON, pulled based on visual signs of BRD; MET, administered a metaphylactic dose of tulathromycin at processing and subsequently pulled based on visual signs of BRD; TEMP, pulled based on visual signs of BRD or elevated ruminal temperature. Number of observations: CON = 6, MET = 7, TEMP = 28.

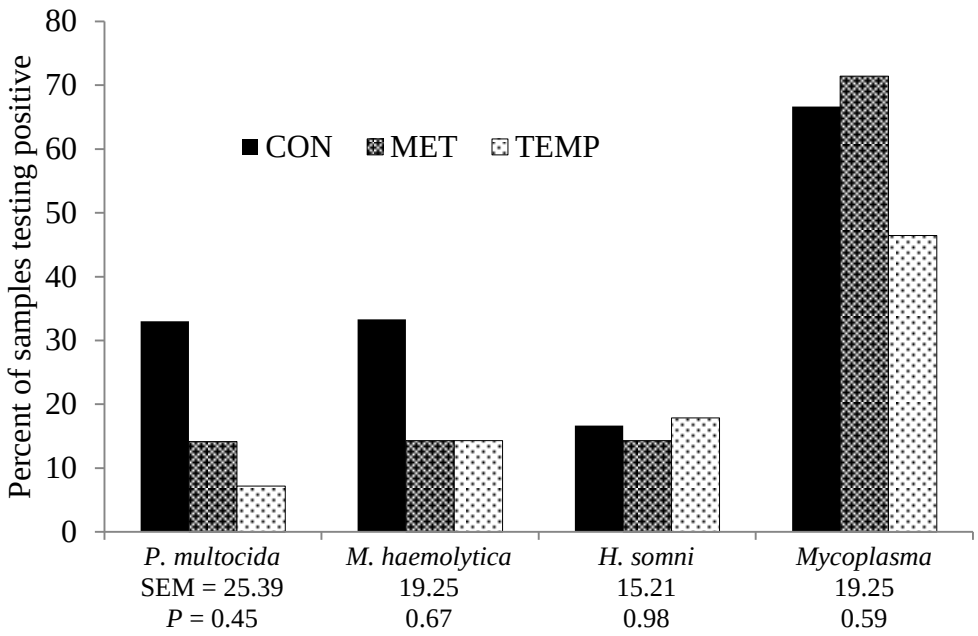

Figure 2.11. Percentage of bronchoalveolar lavage samples testing positive for pathogens related to bovine respiratory disease (BRD) in heifers managed with three BRD management methods at the time of second antimicrobial administration. Management methods: CON, pulled based on visual signs of BRD; MET, administered a metaphylactic dose of tulathromycin at processing and subsequently pulled based on visual signs of BRD; TEMP, pulled based on visual signs of BRD or elevated ruminal temperature. Number of observations: CON = 6, MET = 7, TEMP = 28. Pathogens include *Pasteurella multocida*, *Mannheimia haemolytica*, *Histophilus somni*, and *Mycoplasma spp*.

CHAPTER III

USE OF REMOTE RUMINAL TEMPERATURE MONITORING TO IDENTIFY CATTLE AFFECTED WITH CLINICAL BOVINE RESPIRATORY DISEASE: FINISHING PERFORMANCE, CARCASS TRAITS, AND POST-HARVEST LUNG EVALUATION

ABSTRACT

This experiment evaluated the finishing performance and carcass traits of heifers managed with two bovine respiratory disease (**BRD**) management methods compared to traditional methods. Upon arrival 331 heifers (BW=245±29 kg) were blocked by BW and randomly allotted to 42 pens, which were assigned to one of three BRD management methods: pulled based on visual signs of BRD (CON), administered metaphylaxis at processing and subsequently pulled based on visual signs of BRD (MET), or pulled based on elevated ruminal temperature or visual signs of BRD (TEMP). After a 56-d health monitoring period, heifers were adapted to and maintained on a 94% concentrate diet. Heifers identified with BRD twice began the finishing phase weighing 16.9 kg less ($P <$ 0.01) than all other heifers. Interactions were observed between management method and number of times identified with BRD for final BW and overall ADG ($P \leq 0.02$). Final BW of CON heifers identified with BRD twice was 37.5 kg less ($P < 0.01$) than CON heifers never identified, while number of times identified with BRD did not affect ($P \geq$

0.13) final BW of TEMP and MET heifers. Heifers managed with CON and identified with BRD twice gained 0.16 kg/d less ($P = 0.01$) than other CON heifers, while ADG of TEMP heifers identified with BRD twice was 0.11 kg/d greater ($P = 0.03$) than those never identified, and ADG of MET heifers was unaffected ($P \geq 0.12$) by times identified. Heifers identified with BRD twice had 11.4 kg lighter ($P \leq 0.04$) HCW than those identified zero or one time. Heifers not identified with BRD had 1.1% greater dressing percent ($P < 0.01$), 7.6% greater marbling score ($P \leq 0.04$), and 0.25 cm greater fat thickness ($P \leq 0.02$) compared to heifers identified once or twice with BRD. Carcass value showed a method × number of times identified interaction ($P = 0.04$), as CON heifers identified with BRD twice were valued at $92 less ($P \leq 0.02$) than those from other CON heifers, while carcass value of TEMP and MET heifers was not affected ($P \geq 0.27$) by number of times identified with BRD. Incidence of lung lesions at harvest was low and did not differ ($P \geq 0.46$) among management methods. A greater ($P = 0.03$) percentage of lymph nodes from CON heifers were classified as moderate or severe compared to MET. Results indicate that metaphylaxis and remote temperature monitoring may spare some of the detrimental effects of BRD on performance and carcass value.

KEY WORDS: bovine respiratory disease, carcass, cattle, metaphylaxis, performance, temperature

INTRODUCTION

Bovine respiratory disease (**BRD**) is the most economically significant disease in the U.S. feedlot industry, accounting for up to $900 million in losses annually (Chirase and Greene, 2000). As much as 75% of morbidity and 70% of mortality may be attributed to BRD in feedlot cattle. The effects of BRD are not limited to the time of infection; cattle that experience the disease may exhibit impaired performance throughout the finishing phase. Holland et al. (2010) observed that ADG from arrival through finish decreased linearly as number of BRD treatments increased.

It has been demonstrated by Gardner et al. (1999) that calves treated for BRD have lighter carcass weights compared to calves that were never treated. Additionally, Gardner et al. (1999) observed that calves with lung lesions indicative of BRD at harvest had lower carcass weights, dressing percent, and marbling scores compared to calves with no lung lesions present. These results indicate that quantity and quality of retail product is diminished as the result of BRD.

As BRD severity increases, economic returns are diminished. Schneider et al. (2009) determined that feedlot cattle returned $23.23, $30.15, and $54.01 less than healthy calves when treated once, twice or three or more times for BRD, respectively. Fulton et al. (2002) estimated losses were even greater, with calves treated once, twice, or more times for BRD returning $40.64, $58.35, and $291.93 less than healthy calves, respectively.

Remote ruminal temperature monitoring has the potential to assist in identifying calves suffering from BRD. Ruminal temperatures of calves increase in response to either BRD pathogen challenge (Rose-Dye et al., 2011) or natural infection with BRD

(Sims et al., 2009). The objective of this experiment was to determine if use of remote ruminal temperature monitoring to identify cases of BRD during the receiving phase affects feedlot performance, carcass traits, and post-harvest lung evaluation.

MATERIALS AND METHODS

Cattle and Receiving Phase Procedures

All experimental procedures were approved by the Oklahoma State University Animal Care and Use Committee. This experiment examined the effects of BRD management methods on two separate lots of heifer calves. The first lot was obtained in late May and early June, 2009, and consisted of 148 British × *Bos indicus* heifer calves purchased in Prairieville, LA plus 38 British and British crossbred calves purchased in El Reno, OK. The second lot was purchased in September 2009 and consisted of 180 British and British crossbred calves obtained in Hillsboro, OH.

At the purchase facilities in LA and OH, heifers were administered a unique identification ear tag and a remote ruminal temperature monitoring bolus (Strategic Solutions International, LLC, Stillwater, OK). Heifers were then transported to the Willard Sparks Beef Research Center (**WSBRC**) in Stillwater, OK (1112 km from the LA location, and 1424 km from the OH location). Heifers purchased in OK were first transported 146 km to WSBRC, where they received a unique identification ear tag and ruminal temperature monitoring bolus on arrival.

When heifers arrived at WSBRC, temperature monitoring boluses reported current temperature to a remote computer at a rate of once every 2 min. Bolus signals were received by antennas located on fixed transceiver stations which were designed to

transmit and receive signal data. Antennas were located above each pens' feed bunk and above each automatic water unit, which were located along the fence line and shared between adjacent pens. Signals received by these antennas were then sent to a computer located in the barn via a series of fixed transceiver stations placed in central locations between the pens and the barn. The final transceiver station in the sequence was equipped with a USB port, and logged bolus data in a PostgreSQL database.

Upon arrival at WSBRC, heifers were unloaded and allowed to rest for at least 1 h without access to feed or water. After this resting period, heifers were weighed and skin samples (ear notch) were obtained for testing for persistent infection with bovine viral diarrhea virus (**PI-BVDV**). Heifers were then placed in six open-air pens (12.2 × 30.5 m with 12.2 m of bunk space) where they were allowed to commingle until initial processing, which was between 48 and 72 h later. During this time, heifers had ad libitum access to water and long stem prairie hay.

Heifers were blocked by arrival BW and stratified by coat color and randomly allotted to one of 24 pens. Pens had been randomly assigned to one of three BRD management methods, which consisted of **CON** (pulled based on visual signs of BRD), **MET** [administered 2.5 mg/kg BW tulathromycin (Draxxin, Pfizer Animal Health, Exaton, NY) at processing and subsequently pulled based on visual signs of BRD], and **TEMP** [pulled based on visual signs of BRD or based on elevated ruminal temperature using the Tru-Tag System (Strategic Solutions International)]. At processing (d 0), heifers were administered a clostridial vaccine (Vision 7 with Spur, Intervet/Schering-Plough Animal Health, De Soto, KS), a deworming treatment (Ivomec Plus Injectable, Merial, Duluth, GA), and an implant containing estradiol and trenbolone acetate

(Component TE-G, Vetlife, Overton Park, KS), and were dehorned when necessary. Heifers also received a viral pathogen vaccine. Heifers originating from LA and OK were administered Vista 5 SQ (Intervet/Schering-Plough) at initial processing and Express 5 (Boehringer Ingelheim, St. Joseph, MO) on d 14. Heifers originating from OH received Express 5 at initial processing and 14 d later. Heifers were sent to their newly assigned pens immediately following processing.

The receiving phase lasted for 56 d. Heifers were weighed on d 14, 28, 42, and 56, and were offered the same diet throughout this time. Heifers were maintained on a 63% concentrate ration (Table 3.1) containing monensin (Rumensin 80, Elanco Animal Health, Indianapolis, IN), which was offered ad libitum. Bunks were read each morning, and a daily feed call was made. Feed was then delivered twice daily, once after the morning call, and once in the afternoon. Feed refusals were collected and analyzed for DM at the end of each 14 d period.

Finishing Phase and Harvest

Prior to initiation of the finishing phase, heifers from the first lot were reassigned to 30 pens (n = 4 – 7 per pen) which were 4.57 × 15.24 m and provided 4.57 m of bunk space. A metal awning covered 30% of the length of the pen. These heifers were housed with other calves that had been assigned to the same experimental management method. Heifers from the second lot remained in their original 12 pens through the finishing phase. At initiation of the finishing phase, heifers were adapted to a 94% concentrate finishing ration (Table 3.1) over the course of 28 d. Zilpaterol hydrochloride (Zilmax, Intervet/Schering-Plough) was included in the finishing diet of half of the heifers from

the second lot during the final 23 days on feed, with a 5 d withdrawal period. Inclusion of zilpaterol was distributed evenly among experimental management methods.

Calves received a second implant containing trenbolone acetate and estradiol (Revalor-IH, Intervet/Schering-Plough) at 101 and 68 days on feed for the first and second lots, respectively. Calves were again re-implanted with trenbolone acetate and estradiol (Revalor-H, Intervet/Schering-Plough) at 151 and 124 days on feed for the first lot and the light block of the second lot, respectively. Due to rapid BW gains, the heavy weight block from the second lot did not receive a third implant.

Heifers were fed to a targeted mean final BW of 545 kg, and were harvested by weight block within each lot. Total days on feed for the first lot were 218 and 254 d for the heavy and light weight blocks, respectively. Total days on feed for the second lot were 178 and 199 d for the heavy and light weight blocks, respectively. Final live BW of heifers were measured two d prior to harvest. Heifers were loaded at approximately 0700, and harvested later that afternoon. Heifers from the first lot were shipped 443 km to a commercial abattoir in Dodge City, KS, and heifers from the second lot were shipped 521 km to a commercial abattoir in Amarillo, TX.

At the harvest facility, trained personnel from Oklahoma State University recorded identification information and HCW of all heifers. Following the plants' standard chill protocol, the same personnel also recorded carcass information, including LM area, 12^{th} rib fat thickness, internal fat, KPH, and marbling scores. Quality grades were determined from marbling scores, and yield grades were calculated from HCW, LM area, 12^{th} rib fat thickness, and KPH. Dressing percentages were calculated after

applying a 4% shrink to final live BW. Carcass adjusted final BW, ADG, and G:F were calculated using the mean dressing percentage for each weight block within lot:

$$Carcass\ adjusted\ final\ BW = \frac{HCW}{mean\ dressing\ percent}$$

$$Carcass\ adjusted\ ADG = \frac{(Carcass\ adjusted\ final\ BW) - original\ BW}{days}$$

$$Carcass\ adjusted\ G{:}F = \frac{Carcass\ adjusted\ ADG}{DMI}$$

Post-Harvest Lung Evaluation

At time of harvest, lung pairs were collected off the line at chain speed, and placed in individual bags containing cards which indicated order of harvest. Lungs were then placed on ice and transported back to Stillwater, OK for evaluation at the Oklahoma Animal Disease Diagnostic Laboratory (**OADDL**).

Within 12 h of arrival, lungs were evaluated by two trained individuals for signs of previous or current BRD infection. Evaluators noted presence of collapsed parenchyma, atelectasis, septal expansion, pleuritis, fibrosis, abscesses, and missing lobes. Lymph nodes were classified as normal, mild, moderate, or severe. Percentage of lung affected was noted for each lung (left and right).

Statistical Analysis

To determine the effects of experimental management method on continuous response variables such as BW, ADG, and HCW, data were analyzed using the MIXED procedure of SAS (SAS Institute, Cary, NC). To determine the effects of management methods on categorical response variables, such as quality grades and lung evaluation

scores, data were analyzed using the GLIMMIX procedure of SAS. Pen was considered the experimental unit, and the random effects were lot, weight block, and pen within lot, weight block, and management method combinations. When effects were significant at the $P \leq 0.05$ level, least squares means were separated by pairwise comparison using the PDIFF option. Differences are discussed when $P \leq 0.05$, and are considered tendencies when $0.05 < P \leq 0.10$.

RESULTS

It was determined that no heifers were positive PI-BVDV. Of the 186 heifers from the first lot, 169 completed the project. Causes for removal included death due to BRD (n = 3), extreme illness due to BRD (n = 1), death due to injury (n = 1), poor BW gains (n = 4), bloat (n = 2), lameness (n = 5), and pregnancy (n = 1). Of the 180 heifers received from the second lot, 167 were selected to take part in the project. These heifers included those not requiring treatment for BRD on arrival. Of these 167, 162 completed the project. Causes for removal included death due to BRD (n = 2), extreme illness due to BRD (n = 1), lameness (n = 1), and injury (n = 1).

Finishing Phase Performance

Overall effect of management method. Performance measures of heifers during the finishing phase are shown in Table 3.2. Initial BW of the finishing phase was considered to be the weight at which heifers began adaptation to a high-concentrate diet. For the first lot of heifers, this was 16 d after the completion of the receiving phase. For the second lot of heifers, this was the d after completion of the receiving phase. At the

initiation of the finishing phase, no differences ($P = 0.31$) were evident among the three management methods. Gains of heifers were also not different ($P \geq 0.62$) when measured across the finishing phase or from arrival through finish, resulting in no difference ($P = 0.95$) in final BW. Heifers also had similar DMI during the finishing phase ($P = 0.92$), resulting in no difference ($P = 0.33$) in G:F when measured across the finishing phase. Carcass-adjusted final BW, ADG, and G:F were not different ($P \geq 0.29$) among the management methods.

Effects of management method and times identified with and treated for BRD.

Finishing performance of heifers managed with CON, MET, and TEMP methods and identified with BRD zero, one, or two times is shown in Table 3.3. Initial finishing phase BW was affected ($P < 0.01$) by the number of times heifers were identified with BRD, as heifers identified with BRD twice began the finishing phase weighing 16.9 kg less than heifers identified with BRD zero times or once. There was an interaction ($P = 0.02$) between management method and number of times identified with BRD for final BW. Among CON heifers, those identified with BRD twice weighed 37.5 kg less ($P < 0.01$) at finish than CON heifers never identified with BRD. Heifers managed with MET and TEMP methods did not exhibit differences ($P \geq 0.13$) in final BW due to number of times identified with BRD. Of heifers identified with BRD twice, final BW of TEMP heifers was 42.1 kg greater ($P < 0.01$) than CON. Overall ADG from arrival through finish showed a method by number of times identified with BRD interaction ($P = 0.01$). Among CON heifers, ADG was 0.16 kg/d less ($P = 0.01$) in heifers identified with BRD twice than heifers never identified with BRD and those identified once. Overall ADG of

MET heifers was not affected ($P \geq 0.12$) by number of times identified with BRD. Among TEMP heifers, overall ADG of those identified with BRD twice was 0.11 kg/d greater ($P = 0.03$) than overall ADG of those never identified with BRD. Of heifers identified with BRD twice, TEMP heifers gained 0.21 kg/d more ($P < 0.01$) than CON, while MET heifers identified twice were intermediate. Gains during the finishing phase only were affected ($P = 0.01$) by number of times identified with BRD. Heifers identified with BRD once or twice gained 0.08 kg/d more ($P \leq 0.04$) than heifers never identified with BRD.

Carcass-adjusted BW was affected ($P = 0.04$) by number of times identified with BRD, as heifers identified with BRD twice weighed 18.0 kg less than those identified zero or one times. Carcass-adjusted overall ADG showed an interaction ($P = 0.02$) between management method and number of times identified with BRD. Of heifers managed with the CON method, carcass-adjusted overall ADG of those identified with BRD twice was 0.21 kg/d less ($P < 0.01$) than those identified zero or one times. Carcass-adjusted overall ADG did not differ ($P \geq 0.21$) by number of times identified with BRD in MET and TEMP heifers. Among heifers identified with BRD twice, those managed with the TEMP method gained 0.26 kg/d more ($P < 0.01$) than heifers managed with the CON method. Carcass-adjusted ADG during the finishing phase only was not affected ($P \geq 0.60$) by management method or number of times heifers were identified with BRD.

Effects of management method and number of antimicrobials administered. Finishing performance of heifers managed with CON, MET, and TEMP methods and

administered one, two, or three antimicrobials is shown in Table 3.4. Initial finishing BW was affected ($P \leq 0.02$) by management method and number of antimicrobials administered. Heifers managed with the CON method began the finishing phase weighing 22.7 kg less ($P < 0.05$) than MET and TEMP heifers, which were not different ($P = 0.26$). Heifers administered one antimicrobial began the finishing phase weighing 10.8 kg more ($P = 0.01$) than those administered two, while initial BW of heifers administered three antimicrobials was intermediate. There was a tendency ($P = 0.06$) for management method to affect final BW, as CON heifers tended to weigh 22.7 kg less than MET and TEMP heifers. Overall ADG from arrival through finish showed an interaction ($P = 0.03$) of management method and number of antimicrobials administered. Heifers managed with the CON method and administered one antimicrobial gained 0.16 kg/d more ($P = 0.02$) than those administered two. Overall ADG of MET and TEMP heifers did not differ ($P \geq 0.15$) based on number of antimicrobials administered. Among heifers administered two antimicrobials, CON heifers gained 0.23 kg/d less ($P < 0.01$) than MET and TEMP heifers administered two antimicrobials. Finishing phase ADG was not affected ($P \geq 0.16$) by management method or number of antimicrobials administered.

Carcass-adjusted final BW was affected ($P = 0.05$) by management method, and tended ($P = 0.08$) to be affected by number of antimicrobials administered. Heifers managed with the CON method weighed 28.3 kg less ($P = 0.05$) than TEMP heifers at finish, and MET heifers were intermediate. Heifers administered three antimicrobials tended ($P = 0.07$) to weigh 11.02 kg more than those administered one. Carcass-adjusted overall ADG was affected ($P = 0.01$) by management method, and tended ($P = 0.09$) to be affected by number of antimicrobials administered. Heifers managed with the CON

method gained 0.13 kg/d less ($P = 0.02$) than TEMP heifers, while MET heifers were intermediate. Heifers administered one or two antimicrobials and managed with MET and TEMP methods tended to gain 0.07 kg/d more than MET and TEMP heifers administered three antimicrobials. Carcass-adjusted ADG during the finishing phase only was not affected ($P \geq 0.45$) by management method or by number of antimicrobials administered.

Carcass Traits

Overall effect of management method. Effects of management method on carcass traits of heifers are shown in Table 3.5. No differences ($P \geq 0.13$) were observed in HCW, dressing percent, LM area, 12th rib fat thickness, internal fat, yield grade, or marbling score. Management method also did not affect ($P \geq 0.11$) the percentage of heifers receiving USDA quality grades of select, choice, or prime. Management method did not affect ($P \geq 0.17$) carcass value, when calculated as $/45.5 kg or on a whole-carcass basis.

Effects of management method and times identified with and treated for BRD. Carcass traits of heifers managed with CON, MET, and TEMP methods and identified with BRD zero, one, or two times are shown in Table 3.6. Number of times heifers were identified with BRD affected ($P = 0.04$) HCW. Carcasses from heifers identified with BRD twice weighed 11.4 kg less than carcass from heifers identified with BRD zero times or once, which were not different ($P = 0.75$). Management method and number of times identified with BRD affected ($P < 0.01$) dressing percent. Heifers managed with

the TEMP method had 1.34% greater ($P < 0.01$) dressing percent compared to MET heifers, and tended ($P = 0.08$) to have 0.72% greater dressing percent compared to CON heifers. Dressing percent of CON and MET heifers did not differ ($P = 0.18$). Heifers never identified with BRD had 1.10% greater ($P < 0.01$) dressing percent compared to those identified with BRD once or twice. There was an interaction ($P = 0.01$) of management method and number of times identified with BRD for LM area. Among CON heifers, LM area of those not identified with BRD tended ($P = 0.09$) to be 5.08 cm^2 less than LM area of CON heifers never identified with BRD. Among MET heifers, LM area was not affected ($P \geq 0.37$) by number of times identified with BRD. Among TEMP heifers, LM area was 7.03 cm^2 greater ($P < 0.01$) in heifers identified with BRD once compared to those never identified. Among all heifers never identified with BRD, those managed with the CON method had 4.72 cm^2 greater ($P = 0.04$) LM area than heifers managed with MET and TEMP methods, which were not different ($P = 0.63$). Of heifers identified with BRD once, those managed with the TEMP method had 5.33 cm^2 greater ($P = 0.04$) LM area than heifers managed with the CON method, and LM area of MET heifers was intermediate. Fat thickness was affected ($P = 0.01$) by number of times identified with BRD, with heifers never identified with BRD having 0.25 cm greater ($P \leq 0.02$) fat thickness compared to those identified once or twice, which were not different ($P = 0.40$). Internal fat was not affected ($P \geq 0.24$) by management method or number of times identified with BRD. Yield grade was affected ($P = 0.04$) by number of times identified with BRD, as yield grade of heifers never identified with BRD was 0.43 units greater ($P = 0.01$) than those identified twice, and yield grade of heifers identified once was intermediate. Marbling score differed ($P = 0.03$) by number of times identified with

BRD, with those never identified with BRD scoring 31 units more ($P \leq 0.04$) than those identified once or twice, which were not different ($P = 0.68$). When calculating carcass value on a $/45.5 kg basis, management method and number of times identified with BRD did not affect ($P = 0.45$) value. However, on a whole-carcass basis, value showed an interaction ($P = 0.04$) between management method and number of times identified with BRD. Carcasses from heifers managed with the CON method and identified with BRD twice were valued at $92 less ($P \leq 0.02$) than carcasses from CON heifers identified zero or one time. Carcass value did not differ ($P \geq 0.27$) by number of times identified with BRD in MET and TEMP heifers. Among heifers never identified with BRD, carcasses from CON heifers were valued at $33 more ($P = 0.05$) than MET. Among heifers identified with BRD twice, carcasses from heifers managed with the TEMP method were valued at $102 more ($P < 0.01$) than CON heifers identified twice.

Effects of management method and number of antimicrobials administered.

Carcass traits of heifers managed with CON, MET, and TEMP methods and administered one, two, or three antimicrobials are shown in Table 3.7. Management method affected ($P = 0.05$) HCW, and number of antimicrobials administered tended ($P = 0.08$) to affect HCW. Carcasses from heifers managed with the CON method weighed 17.9 kg less than TEMP, while HCW of carcasses from MET heifers was intermediate. Carcasses from heifers administered two antimicrobials tended to be 7.0 kg lighter than carcasses from heifers administered one antimicrobial. Dressing percent was affected ($P = 0.03$) by number of antimicrobials administered, as dressing percent of heifers administered one antimicrobial was 0.85% greater ($P \leq 0.03$) than those administered two or three.

Management method and number of antimicrobials administered did not affect ($P \geq 0.11$) LM area, fat thickness, internal fat, yield grade, or marbling score. Value of carcasses were not affected ($P \geq 0.11$) by management method or number of antimicrobials administered, when calculated as $/45.5 kg, or on a whole-carcass basis.

Post-Harvest Lung Evaluation

Lungs from 298 heifers were accurately identified and returned to OADDL for evaluation. Results for lung assessment scores are shown in Table 3.8. Percent of lungs categorized as 0 (normal), 1 (mild), or 2 or 3 (moderate or severe) for pneumonia, pleural fibrosis, or intralobular fibrosis did not differ ($P \geq 0.46$) by management method. A greater ($P = 0.03$) percentage of CON lymph nodes were categorized as moderate or severe compared to MET. Also, there was a tendency ($P = 0.07$) for a greater percentage of CON lymph nodes to be classified as moderate or severe compared to TEMP.

Results for percent of lung affected by abnormalities are shown in Table 3.9. Among lungs with pneumonia present, there was a tendency ($P = 0.10$) for a greater percentage of the lung to be affected in MET heifers compared to CON. Percent of lung affected with pleural fibrosis, percent of lung affected with intralobular fibrosis, and percent of lung missing were not affected ($P \geq 0.66$) by management method.

DISCUSSION

Initial finishing phase BW is reflective of performance and health during the receiving phase, as heifers requiring multiple treatments for BRD did not perform as well as those never identified with BRD or those administered only one antimicrobial.

Compensatory gains were observed during the finishing phase in some heifers identified with BRD once or twice. These increased gains were not sufficient for CON heifers identified with BRD twice to reach the same final BW as other CON heifers, but for MET and TEMP heifers, compensatory gains did result in similar BW among heifers identified with BRD zero, one, or two times. Some researchers have found no difference in overall ADG in cattle treated for BRD (Jim et al., 1993; Wittum et al., 1996) indicating that some morbid cattle are able to compensate for reduced performance experienced in the early phase of the feeding period. Others have observed diminished overall performance in cattle treated for BRD (Gardner et al., 1999; Montgomery et al., 2009; Schneider et al., 2009) indicating that there are also times when compensatory gains during the later periods are not sufficient to overcome reduced performance from the receiving phase. Holland et al. (2010) observed decreasing BW during the finishing phase as number of treatments for BRD during the preconditioning period increased. Heifers were fed to a common backfat thickness, and with no differences in ADG, those treated for BRD three times required a greater number of days on feed (Holland et al., 2010). Heifers in that experiment were treated for BRD based on visual assessment, similar to CON heifers in the present experiment. It appears that metaphylaxis and temperature monitoring spared some of the detrimental effects of BRD on performance, as decreases in final BW due to multiple BRD treatments were only observed in CON heifers.

Increased frequency of treatment for BRD is oftentimes associated with depressed carcass quality. Cattle treated for BRD have exhibited lower HCW, dressing percent, fat thickness, yield grade, and marbling scores (Garcia et al., 2010; Montgomery et al., 2009;

Roeber et al., 2001; Schneider et al., 2009; Snowder et al., 2007). Results from the present experiment are in agreement with those from previous studies. However, greater HCW of TEMP heifers administered one, two, or three antimicrobials compared to CON heifers administered one or two antimicrobials provides further evidence that temperature monitoring spared some of the detrimental effects of BRD when compared to traditional visual assessment methods. While finishing performance was not different between MET and TEMP heifers, it is interesting to note that dressing percent was greater in TEMP heifers identified with BRD zero, one, or two times compared to MET. When accounting for the metaphylactic dose given to MET heifers, the frequency of treatment for BRD did not differ between these two methods (Chapter II). There was also evidence based on ruminal temperatures during the receiving phase that a greater level of subclinical disease may have been present in MET heifers compared to TEMP (Chapter II). Data may suggest that targeting treatment to calves based on elevated ruminal temperature may help to maximize some carcass traits, such as dressing percent.

Temperature monitoring was not successful in improving other carcass measures when also considering frequency of treatment for BRD. However, carcass value was improved in TEMP heifers identified with BRD twice compared to CON. This is likely the result of greater HCW, and therefore quantity of retail product, as the quality of the product was not affected by management method, as indicated by similar marbling scores among CON and TEMP heifers. Net economic returns have been shown to decrease dramatically as frequency of treatment for BRD increases (Fulton et al., 2002; Schneider et al., 2009). In the present study, costs associated with changes in feed efficiency and antimicrobial treatments were not considered. It is still notable that gross returns were

not affected when metaphylaxis or ruminal temperature monitoring were employed as management tools. As calves managed with these methods were administered a greater number of antimicrobials, it is likely that overall economic benefit was marginal.

Presence of lung lesions at harvest has been evaluated as an indicator of incidence of both clinical and subclinical BRD in cattle. Wittum et al. (1996) indicated that of 469 steers evaluated, 35% received treatment for BRD; however, 72% of steers had lung lesions evident of BRD at harvest. Additionally, of the steers not treated for BRD, 68% had lung lesions. Average daily gains of these steers were 0.076 kg less than that of steers that did not have lung lesions. Gardner et al. (1999) conducted an experiment utilizing 209 steers, and 50% were treated for BRD. At harvest, lung lesions were evident in 43% of steers; however, distributions of lesions were similar between steers that had and had not been treated for BRD (Gardner et al., 1999). Buhman et al. (2000) examined 170 feedlot heifers originating from auction markets in the Southeast and subsequently fed in Texas. Of these, 43% were treated for BRD, while 87% had lung lesions present at harvest, and 83% of calves that had never been identified as sick had lung lesions at harvest (Buhman et al., 2000).

In the present study, overall incidence of lung lesions at harvest were low, and percent of severity scores was unaffected by management method. It was hypothesized that use of metaphylaxis and rumen temperature monitoring could result in reduced frequency of lung lesions at harvest; however, the low incidence of lesions across all management methods was not sufficient to provide statistically different results. It must also be considered that presence of chronic fibrosis indicates previous lung infection, but it cannot be determined if the infection occurred prior to or after entry into the feedlot.

Therefore, results may indicate that overall incidence of infection was similar among management methods, but timing of infection cannot be measured. As occurrence of active infection was rare, lymph node scores may provide a better indicator of active inflammatory processes in these calves. Heifers managed using the CON method exhibited increased lymph node inflammation compared to MET and TEMP heifers, indicating that infection in the chest region was reduced as a result of metaphylaxis and ruminal temperature monitoring.

These data indicate that temperature monitoring has potential to identify subclinical cases of BRD. In order to successfully utilize this system a number of additional factors must be considered, including effects of environment, diet, breed type, and reproductive cycling in heifers. Further research is needed to quantify differences in ruminal temperature due to each of these factors as well as onset of BRD in order to better predict a need for antimicrobial therapy, and to enhance efficiency of temperature monitoring as a diagnostic tool.

LITERATURE CITED

Buhman, M. J., L. J. Perino, M. L. Galyean, T. E. Wittum, T. H. Montgomery, and R. S. Wingle. 2000. Association between changes in eating and drinking behaviors and respiratory tract disease in newly arrived calves at a feedlot. Am. J. Vet. Res. 61:1163-1168.

Chirase, N. K, and Greene, L. W. 2000. Influence of oral natural interferon-alpha on performance and rectal temperature of newly received beef steers. Western Section Am. Soc. Anim. Sci. Proc. 51:411-414.

Fulton, R. W., B. J. Book, D. L. Step, A. W. Confer, J. T. Saliki, M. E. Payton, L. J. Burge, R. D. Welsh, K. S. Blood. 2002. Evaluation of health status of calves and the impact on feedlot performance: assessment of a retained ownership program for postweaning calves. Can. J. Vet. Res. 66:173-180.

Garcia, M. D., R. M. Thallman, T. L. Wheeler, S. D. Shackelford, and E. Casas. 2010. Effect of bovine respiratory disease and overall pathogenic disease incidence on carcass traits. J. Anim. Sci. 88:491-496.

Gardner, B. A., H. G. Dolezal, L. K. Bryant, F. N. Owens, and R. A. Smith. 1999. Health of finishing steers: effects on performance, carcass traits, and meat tenderness. J. Anim. Sci. 77:3168-3175.

Holland, B. P., L. O. Burciaga-Robles, D. L. VanOverbeke, J. N. Shook, D. L. Step, C. J. Richards, and C. R. Krehbiel. 2010. Effect of bovine respiratory disease during preconditioning on subsequent feedlot performance, carcass characteristics, and beef attributes. J. Anim. Sci. 88:2486-2499.

Jim, G. K., C. W. Booker, C. S. Ribble, P. T. Guichon, B. E. Thorlakson. 1993. A field investigation of the economic impact of respiratory disease in feedlot calves. Can. Vet. J. 34:668-673.

Montgomery, S. P., J. J. Sindt, M. A. Greenquist, W. F. Miller, J. N. Pike, E. R. Loe, M. J. Sulpizio, and J. S. Drouillard. 2009. Plasma metabolites of receiving heifers and the relationship between apparent bovine respiratory disease, body weight gain, and carcass characteristics. J. Anim. Sci. 87:328-333.

Roeber, D. L., N. C. Speer, J. G. Gentry, J. D. Tatum, C. D. Smith, J. C. Whittier, G. F. Jones, K. E. Belk, and G. C. Smith. 2001. Feeder cattle health management: Effects on morbidity rates, feedlot performance, carcass characteristics, and beef palatability. Prof. Anim. Sci. 17:39-44.

Rose-Dye, T. K., L. O. Burciaga-Robles, C. R. Krehbiel, D. L. Step, R. W. Fulton, A. W. Confer, and C. J. Richards. 2011. Rumen temperature change monitored with remote rumen temperature boluses after challenges with bovine viral diarrhea virus and *Mannheimia haemolytica*. J. Anim. Sci. 89:1193-1200.

Schneider, M. J., R. G. Tait, Jr., W. D. Busby, and J. M. Reecy. 2009. An evaluation of bovine respiratory disease complex in feedlot cattle: Impact on performance and carcass traits using treatment records and lung lesion scores. J. Anim. Sci. 87:1821-1827.

Sims, L. E., T. K. Dye-Rose, C. L. Goad, B. P. Holland, L. O. Burciaga-Robles, D. L. Step, C. R. Krehbiel, and C. J. Richards. 2009. Use of rumen temperature for health monitoring in cattle. J. Anim. Sci. 87(E-Suppl 2): 120. (Abstr.)

Snowder, G. D., L. D. Van Vleck, L. V. Cundiff, G. L. Bennett, M. Koohmaraie, and M. E. Dikeman. 2007. Bovine respiratory disease in feedlot cattle: Phenotypic, environmental, and genetic correlations with growth, carcass, and longissimus muscle palatability traits. J. Anim. Sci. 85:1885-1892.

Wittum, T. E., N. E. Woollen, L. J. Perino, and E. T. Littledike. 1996. Relationships among treatment for respiratory tract disease, pulmonary lesions evident at slaughter and rate of weight gain in feedlot cattle. J. Am. Vet. Med. Assoc. 209:814-818.

Table 3.1. Ingredient and nutrient composition of diets

	Diet	
Item	Receiving	Finishing
Ingredient, %		
Dry rolled corn	35.5	70.0
Dried distillers grains	18.0	12.0
Ground prairie hay	19.0	6.0
Ground alfalfa hay	18.0	-
Liquid supplement[1]	3.5	6.0
Dry supplement[2]	6.0	6.0
Nutrient		
DM, %	87.44	76.58
NE_m, Mcal/kg	1.57	2.15
NE_g, Mcal/kg	0.97	1.40
CP, %	14.5	13.3
ADF, %	18.9	6.7
NDF, %	32.6	16.2
Ca, %	0.65	0.69
P, %	0.34	0.38

[1]Synergy 19/14 (Westway Feed Products, New Orleans, LA).
[2]Pelleted supplement contained the following (DM basis): Receiving diet: 60.14% ground corn, 16.67% wheat middlings, 15% limestone, 1.67% urea, 4.16% salt, 1.67% magnesium oxide, 0.04% manganous oxide, 0.33% zinc sulfate, 0.07% vitamin A (30,000 IU/g), 0.04% vitamin E (50%), and 0.21% Rumensin 80 (Elanco Animal Health, Indianapolis, IN). Finishing diet: 45.65% ground corn, 16.67% wheat middlings, 25.83% limestone, 4.00% salt, 3.33% urea, 1.83% potassium chloride, 1.67% magnesium oxide, 0.05% manganous oxide, 0.25% zinc sulfate, 0.05% vitamin A (30,000 IU/g), 0.04% vitamin E (50%), 0.13% MGA 200 (Pharmacia & Upjohn Company, Kalamazoo, MI), 0.31% Rumensin 80, and 0.19% Tylan 40 (Elanco Animal Health).

Table 3.2. Effect of management method on finishing performance and intake of heifers

	Management Method[1]				
Item	CON	MET	TEMP	SEM	*P*-Value
Initial BW,[2] kg	349.48	351.7	348.36	33.8	0.47
Final BW, kg	494.0	492.2	493.4	12.3	0.95
ADG: arrival – finish, kg	1.19	1.19	1.19	0.13	0.96
ADG: finishing phase, kg[3]	1.09	1.06	1.09	0.27	0.62
DMI, kg/d[3]	8.09	8.08	8.03	0.44	0.92
G:F[3]	0.134	0.130	0.134	0.026	0.33
Carcass adjusted traits[4]					
Final BW, kg	494.5	491.0	495.8	12.7	0.80
ADG: arrival – finish, kg	1.19	1.19	1.20	0.13	0.84
ADG: finishing phase, kg[3]	1.09	1.05	1.11	0.27	0.47
G:F[3]	0.134	0.128	0.136	0.027	0.29

[1]Management method: CON = pulled based on visual signs of bovine respiratory disease (BRD), MET = administered a metaphylactic dose of tulathromycin at processing and subsequently pulled based on visual signs of BRD, TEMP = pulled based on visual signs of BRD or elevated ruminal temperature.
[2]BW at the beginning of the finishing phase (56 or 96 d after arrival).
[3]Traits measured during the finishing phase (56 or 96 d after arrival until finish).
[4]Calculated based on mean dressing percent by weight block within lot.

Table 3.3. Finishing phase performance of heifers managed with three bovine respiratory disease (BRD) management methods and identified with and treated for BRD zero, one, or two times

	Management Method[1]												
	CON			MET			TEMP				*P*-Values[2]		
Item[3]	0	1	2	0	1	2	0	1	2	SEM	M	T	M×T
Initial BW, kg[4,6]	353.3	343.3	317.1	353.5	346.2	335.8	357.8	358.3	352.6	34.8	0.14	<0.01	0.10
Final BW, kg	500.1^{b}	489.5^{b}	462.6^{a}	491.7^{b}	504.0^{b}	484.2^{ab}	488.9^{ab}	497.4^{b}	504.7^{b}	15.6	0.34	0.20	0.02
oADG, kg	1.20^{bc}	1.20^{bc}	1.04^{a}	1.19^{bc}	1.27^{c}	1.19^{bc}	1.15^{ab}	1.20^{bc}	1.25^{c}	0.14	0.06	0.12	0.01
fADG, kg[7]	1.08	1.11	1.10	1.05	1.20	1.14	1.01	1.07	1.14	0.27	0.29	0.01	0.33
Carcass adjusted traits, kg[5]													
BW[6]	502.7	488.0	455.9	492.1	492.3	472.2	496.6	499.8	503.7	16.6	0.15	0.04	0.07
oADG[8]	1.21^{b}	1.18^{b}	0.99^{a}	1.20^{b}	1.22^{b}	1.13^{ab}	1.19^{b}	1.21^{b}	1.25^{b}	0.15	0.05	0.08	0.02
fADG	1.11	1.09	1.03	1.05	1.11	1.05	1.08	1.09	1.14	0.28	0.73	0.87	0.60

[1]Management method: CON = pulled based on visual signs of BRD, MET = administered a metaphylactic dose of tulathromycin at processing and subsequently pulled based on visual signs of BRD; TEMP, pulled based on visual signs of BRD or elevated ruminal temperature.
[2]Comparisons: M, effect of management method; T, effect of times identified with and treated for BRD; M×T, interaction of M and T.
[3]oADG = overall ADG from arrival through finish; fADG = ADG during the finishing phase (56 or 96 d after arrival through finish).
[4]BW at the beginning of the finishing phase (56 or 96 d after arrival).
[5]Calculated based on mean dressing percent by weight block within lot.
[6]T effect: 0, 1 > 2 ($P \leq 0.05$).
[7]T effect: 0 < 1, 2 ($P \leq 0.05$).
[8]M effect: CON < TEMP ($P \leq 0.05$).
[abc]Means within a row without a common superscript differ ($P \leq 0.05$).

Table 3.4. Finishing phase performance of heifers managed with three bovine respiratory disease (BRD) management methods and administered one, two, or three antimicrobials

	Management Method[1]											
	CON		MET			TEMP				*P*-Values[2]		
Item[3]	1	2	1	2	3	1	2	3	SEM	M	A	M×A
Initial BW, kg[4,6,7]	338.4	315.2	352.7	345.6	335.2	358.7	356.4	348.1	35.4	0.02	<0.01	0.23
Final BW, kg	486.8	459.8	491.4	503.5	483.7	498.2	504.7	494.3	16.3	0.06	0.33	0.16
oADG, kg	1.19[b]	1.03[a]	1.19[b]	1.27[b]	1.18[ab]	1.20[b]	1.25[b]	1.19[b]	0.15	0.02	0.42	0.03
fADG, kg	1.10	1.09	1.05	1.19	1.13	1.08	1.14	1.12	0.28	0.08	0.16	0.33
Carcass adjusted traits, kg[5]												
BW[8]	485.8	454.2	491.6	491.8	471.3	500.4	502.8	491.9	16.4	0.05	0.08	0.26
oADG[8]	1.18	0.99	1.20	1.21	1.12	1.21	1.25	1.18	0.16	0.01	0.09	0.06
fADG	1.08	1.02	1.06	1.11	1.05	1.09	1.13	1.10	0.30	0.45	0.89	0.64

[1]Management method: CON = pulled based on visual signs of BRD, MET = administered a metaphylactic dose of tulathromycin at processing and subsequently pulled based on visual signs of BRD, TEMP = pulled based on visual signs of BRD or elevated ruminal temperature.
[2]Comparisons: M = effect of management method, A = effect of number of antimicrobials administered for BRD, M×A = interaction of M and A.
[3]oADG = overall ADG from arrival through finish; fADG = ADG during the finishing phase (56 or 96 d after arrival through finish).
[4]BW at the beginning of the finishing phase (56 or 96 d after arrival).
[5]Calculated based on mean dressing percent by weight block within lot.
[6]M effect: CON < MET, TEMP ($P \leq 0.05$).
[7]A effect: 1 < 2 ($P \leq 0.05$).
[8]M effect: CON < TEMP ($P \leq 0.05$).
[ab]Means within a row without a common superscript differ ($P \leq 0.05$).

Table 3.5. Effect of management method on carcass characteristics of heifers

	Management Method[1]				
Item	CON	MET	TEMP	SEM	*P*-Value
HCW, kg	312.6	310.4	313.3	8.4	0.80
Dressing percent	63.17	62.95	63.44	0.43	0.40
LM area, cm^2	79.21	75.98	78.29	3.39	0.13
Fat thickness, cm	1.32	1.46	1.44	0.15	0.39
Internal fat, %	2.29	2.27	2.43	0.42	0.50
Yield grade	2.43	2.62	2.44	0.16	0.22
USDA Quality Grade, %					
Select	18.28	30.29	29.89	8.06	0.11
Choice	74.80	65.34	66.73	6.97	0.27
Prime	2.83	1.74	0.90	1.61	0.60
Marbling score[2]	427	421	428	10	0.85
$/45.5 kg	144	142	143	5	0.17
$/carcass	983	965	977	33	0.51

[1]Management method: CON = pulled based on visual signs on bovine respiratory disease (BRD), MET = administered a metaphylactic dose of tulathromycin on arrival and subsequently pulled based on visual signs of BRD, TEMP = pulled based on visual signs of BRD or elevated ruminal temperature.
[2]400 = small, 500 = modest.

Table 3.6. Carcass traits of heifers managed with three bovine respiratory disease (BRD) management methods and identified with and treated for BRD zero, one, or two times

	Management Method[1]												
	CON			MET			TEMP				*P*-Values[2]		
Item	0	1	2	0	1	2	0	1	2	SEM	M	T	M×T
HCW, kg[4]	318.1	308.9	288.5	311.5	311.7	298.9	314.3	316.4	319.0	10.7	0.15	0.04	0.06
Dressing percent[5,6]	63.62	63.07	62.34	63.36	61.94	61.85	64.35	63.64	63.20	0.93	<0.01	<0.01	0.83
LM area, cm^2	80.43^{bc}	76.81^{ab}	73.89^{bc}	76.32^{a}	79.03^{abc}	77.17^{abc}	75.11^{a}	82.14^{c}	80.21^{abc}	6.29	0.59	0.32	0.01
Fat thickness, cm[6]	1.39	1.33	1.03	1.48	1.22	1.24	1.63	1.34	1.31	0.29	0.32	0.01	0.68
Internal fat, %	2.46	2.19	1.93	2.28	2.20	2.10	2.36	2.39	2.52	0.72	0.24	0.41	0.42
Yield grade[7]	2.43	2.45	2.02	2.63	2.31	2.12	2.55	2.29	2.18	0.36	0.97	0.04	0.69
Marbling score[3,6]	442	423	409	422	406	404	463	415	409	34	0.52	0.03	0.80
$/45.5 kg	144	143	142	143	143	144	143	143	143	7	0.99	0.91	0.45
$/carcass	1008^{c}	979^{bc}	902^{a}	975^{b}	985^{bc}	946^{ab}	986^{bc}	993^{bc}	1004^{bc}	66	0.18	0.07	0.04

[1]Management method: CON = pulled based on visual signs of BRD, MET = administered a metaphylactic dose of tulathromycin on arrival and subsequently pulled based on visual signs of BRD, TEMP = pulled based on visual signs of BRD or elevated ruminal temperature.
[2]Comparisons: M = effect of management method, T = effect of number of times identified with and treated for BRD, M×T = interaction of M and T.
[3]400 = small, 500 = modest.
[4]T effect: 0, 1 > 2 ($P \leq 0.05$).
[5]M effect: MET < TEMP ($P \leq 0.05$).
[6]T effect: 0 > 1, 2 ($P \leq 0.05$).
[7]T effect: 0 > 2 ($P \leq 0.05$).
[abc]Means within a row without a common superscript differ ($P < 0.05$).

Table 3.7. Carcass traits of heifers managed with three bovine respiratory disease (BRD) management methods and administered one, two, or three antimicrobials

	Management Method[1]											
	CON		MET			TEMP				*P*-Values[2]		
Item	1	2	1	2	3	1	2	3	SEM	M	A	M×A
HCW, kg[4]	307.7	287.6	311.0	311.1	298.3	316.7	318.3	311.3	11.2	0.05	0.08	0.26
Dressing percent[5]	63.13	62.46	63.33	61.98	61.92	63.62	63.19	63.05	0.88	0.11	0.03	0.60
LM area, cm^2	76.70	73.29	76.42	79.60	78.20	81.97	80.51	75.74	0.82	0.22	0.35	0.15
Fat thickness, cm	1.31	1.04	1.48	1.23	1.23	1.34	1.29	1.40	0.28	0.35	0.11	0.41
Internal fat, %	2.23	1.95	2.29	2.20	2.07	2.38	2.54	2.33	0.74	0.18	0.19	0.30
Yield grade	2.51	2.10	2.62	2.32	2.12	2.28	2.18	2.53	0.38	0.96	0.24	0.28
Marbling score[3]	425	414	421	409	410	415	410	410	35	0.96	0.83	0.99
$/45.5 kg	143	142	142	143	144	143	143	141	7	0.61	0.83	0.32
$/carcass	981	905	974	983	944	993	1003	963	67	0.14	0.11	0.22

[1]Management method: CON = pulled based on visual signs of BRD, MET = administered a metaphylactic dose of tulathromycin at processing and subsequently pulled based on visual signs of BRD, TEMP = pulled based on visual signs of BRD or elevated ruminal temperature.
[2]Comparisons: M = effect of management method, A = effect of number of antimicrobials administered for BRD, M×A = interaction of M and A.
[3]400 = small, 500 = modest.
[4]M effect: CON < TEMP ($P \leq 0.05$).
[5]A effect: 1 > 2, 3 ($P \leq 0.05$).

Table 3.8. Distribution of lung assessment scores

	Management Method[1]				
Item[2]	CON	MET	TEMP	SEM	*P*-Value
Pneumonia, %					
0	88.94	88.97	91.35	4.99	0.79
1	9.27	8.55	8.21	4.06	0.96
2 or 3	3.19	3.00	1.00	1.81	0.69
Pleural fibrosis, %					
0	75.79	76.16	76.32	8.25	0.99
1	14.20	17.90	19.68	6.09	0.59
2 or 3	5.79	5.01	4.34	3.86	0.88
Intralobular fibrosis, %					
0	82.94	76.03	79.10	4.41	0.49
1	15.97	22.84	18.74	4.49	0.46
2 or 3	0.38	0.38	0.71	1.19	0.82
Lymph nodes, %					
0	72.49	83.42	86.07	10.00	0.11
1	14.97	15.33	11.29	6.57	0.76
2 or 3	12.39[b]	1.40[a]	2.98[ab]	4.65	0.03

[1]Management Methods: CON = pulled based on visual signs of bovine respiratory disease (BRD), MET = administered a metaphylactic dose of tulathromycin at processing and subsequently pulled based on visual signs of BRD, TEMP = pulled based on visual signs of BRD or elevated ruminal temperature.
[2]Scores within each item: 0 = normal, 1 = mild, 2 or 3 = moderate or severe.
[ab]Means within a row without a common superscript differ ($P \leq 0.05$).

Table 3.9. Percentage of lung affected by abnormalities observed during post-harvest evaluation

	Management Method[1]				
Item	CON	MET	TEMP	SEM	*P*-Value
% of lung affected					
Pneumonia[2]	4.62	9.93	6.80	1.74	0.10
Pleural fibrosis[3]	5.85	6.52	6.20	1.47	0.95
Intralobular fibrosis[4]	23.01	18.39	18.74	4.03	0.66
Missing, %[5]	2.06	2.63	2.90	1.45	0.88

[1]Management Methods: CON = pulled based on visual signs of bovine respiratory disease (BRD), MET = administered a metaphylactic dose of tulathromycin at processing and subsequently pulled based on visual signs of BRD, TEMP = pulled based on visual signs of BRD or elevated ruminal temperature.
[2]Percent of lung affected by pneumonia in lungs with evidence of pneumonia
[3]Percent of lung affected by pleural fibrosis in lungs with pleural fibrosis present.
[4]Percent of lung affected by intralobular fibrosis in lungs with intralobular fibrosis present.
[5]Percent of lung missing, indicating thoracic adhesion.

CHAPTER IV

RESULTS OF BRONCHOALVEOLAR LAVAGE CULTURES, RUMINAL TEMPERATURES, AND PERFORMANCE IN HIGH-RISK HEIFERS FOLLOWING METAPHYLAXIS

ABSTRACT

The objective of this experiment was to measure effects of origin and metaphylaxis on bronchoalveolar lavage cultures, ruminal temperature, and performance of heifers. This experiment utilized 40 mixed-breed high-risk beef heifers originating from KY and LA. Heifers were assigned to a standard feedlot protocol (CON) or administered metaphylaxis at initial processing (MET). Bronchoalveolar lavage samples were obtained at initial processing (day 0), and at days 4, 8 and 14. Heifers were administered ruminal temperature monitoring boluses which reported every three minutes. Results were evaluated by origin, processing method, and day after processing. Prevalence of potential pathogenic species was greater ($P < 0.05$) in KY heifers compared to LA. Treatment did not affect ($P \geq 0.73$) percent of positive samples for *Mannheimia haemolytica* or *Mycoplasma* spp; however, a trend ($P = 0.08$) for increased *Pasteurella multocida* in CON samples was noted. Metaphylaxis decreased ($P < 0.05$) ruminal temperature after processing. Origin did not affect ($P \geq 0.13$) body weight or overall average daily gain (ADG). Use of MET improved body weight on days 14, 28, and 56 ($P \leq 0.04$), increased

ADG during the first 14 days ($P = 0.02$), and tended ($P = 0.07$) to increase ADG alter the population of potential bovine respiratory disease-causing bacteria in bronchoalveolar lavage cultures. Use of metaphylaxis should be targeted to those calves that are at greatest risk for developing clinical bovine respiratory disease.

KEY WORDS: Beef cattle, bovine respiratory disease, bronchoalveolar lavage, metaphylaxis, temperature

INTRODUCTION

Bovine respiratory disease (**BRD**) is the most prevalent cause of morbidity and mortality of feedlot cattle, and results in economic losses estimated at over $800 million annually (NASS, 2006; Chirase and Greene, 2000). Feedlot cattle are most susceptible to BRD upon entry into the feedlot, as calves experience the stresses of weaning, commingling, and shipping during this time (Duff and Galyean, 2007).

Many producers have utilized metaphylaxis as a management tool to prevent BRD in newly received feedlot calves (Jim et al., 1999). Incidence of BRD morbidity of high-risk calves decreased to 13% as a result of metaphylaxis using tulathromycin, compared to 58% in calves not receiving metaphylaxis (Kilgore et al., 2005). A meta-analysis determined that metaphylaxis decreases BRD-related morbidity from 55% to 29% and mortality from 3.8% to 1.8% (Wileman et al., 2009). The length of the recommended post-treatment interval varies among medications (Apley, 2006), and little research has investigated the changes occurring in pathogens present in the airways of the lung during this interval.

Identification of cattle suffering from BRD is commonly based on subjective evaluation of individual animals. After cattle have been identified as possibly suffering from BRD, most producers and veterinarians use rectal temperature as an objective measure for determining which animals are candidates to receive antimicrobial therapy. It is accepted that the earlier in the disease process antimicrobial administration occurs, the better and more rapid the response an animal exhibits.

There is potential for ruminal temperature monitoring to be used as a method of detection of respiratory disease in calves. Ruminal temperature has been shown to be highly correlated with rectal temperature, and calves administered multiple treatments for BRD have exhibited higher ruminal temperatures compared to calves not identified with clinical BRD (Sims et al., 2009; Bewley et al., 2008). It is hypothesized that bacterial pathogen populations present in the lungs of calves are altered by metaphylactic antimicrobial administration, and that ruminal temperatures decrease with metaphylaxis. The objective of this experiment was to determine how metaphylaxis affects bronchoalveolar lavage (**BAL**) cultures, ruminal temperature, and performance of high-risk feedlot calves.

MATERIALS AND METHODS

All experimental procedures were approved by the Oklahoma State University Institutional Animal Care and Use Committee.

Cattle

This experiment was conducted on heifer calves originating from two different locations. The first group (**LA**) consisted of 99 British × *Bos indicus* calves originating

around and gathered at a buying station in Prairieville, LA in May, 2009 with a mean initial body weight (**BW**) of 246 ± 37 kg. The second group (**KY**) consisted of 111 British and British crossbred calves originating from a single auction market in Lexington, KY in September, 2009 with a mean initial BW of 245 ± 21 kg. Heifers from the KY lot were transported 179 km to a gathering location in Hillsboro, OH prior to delivery. At the gathering facilities, heifers were administered a remote ruminal temperature monitoring bolus (Strategic Solutions International; Stillwater, OK), and were transported to the Oklahoma State University Willard Sparks Beef Research Center (**WSBRC**) in Stillwater, OK. Heifers originating from LA traveled 1,112 km, and heifers originating from KY traveled 1,423 km.

Upon arrival, calves were allowed to rest for approximately one hour in an open-air, dirt floor lot without access to feed or water. After this rest time, calves were weighed and skin samples (ear notches) were obtained to test for persistent infection with bovine viral diarrhea virus. Gender was also confirmed at this time. Calves were allowed to commingle in six pens (12.2 × 30.5 m, 12.2 m of bunk space), and were offered ad libitum access to water and long-stemmed prairie hay until initial processing (day 0), which was 48-72 hours post-arrival.

At initial processing, calves were administered a viral respiratory vaccine (Vista 5 SQ, Intervet/Schering-Plough, DeSoto, KS; Express 5, Boehringer Ingelheim Vetmedica, St. Joseph, MO), a clostridial vaccine (Vision 7 with Spur, Intervet/Schering-Plough), an endectocide treatment (Ivomec Plus Injectable, Merial, Duluth, GA), and an implant containing estradiol and trenbalone acetate (Component TE-G, Vetlife, Overton Park, KS), and were dehorned when necessary. Heifers were revaccinated with the viral

respiratory vaccine 14 days later. All products were administered following beef quality assurance guidelines.

Calves were blocked by BW and stratified by coat color, and randomly allotted to one of 16 pens, which had been randomly assigned to one of two BRD management methods (eight pens per method). Management methods included the standard feedlot protocol, in which calves were pulled based on visual signs of clinical BRD (**CON**), or administered a tulathromycin (Draxxin, Pfizer Animal Health, Exaton, NY; 2.5 mg/kg) metaphylactic treatment subcutaneously in the neck at day 0 processing and subsequently pulled after a seven day post-metaphylactic interval based on visual signs of clinical BRD (**MET**). Within each place of origin, three heifers from each MET pen, and two heifers from each CON pen were randomly selected for the experiment, resulting in a total of 40 calves. After day 0, heifers were weighed on days 14, 28, 42, and 56 to measure performance throughout a typical receiving phase.

Identification of and Treatment for BRD

All heifers were visually evaluated each morning at approximately 0700 for signs consistent with BRD by two trained individuals who were blinded to experimental management methods. Criteria for pulls were based on the DART system (Pharmacia & Upjohn Animal Health, Kalamazoo, MI). Signs of clinical BRD included depression (**D**; hanging head, sunken eyes, drooping ears, stiffness), appetite (**A**; lack of fill compared to penmates, off feed, eating less than or with less aggression than penmates), and respiratory signs (**R**; labored breathing, extended neck and head, noisy breathing). Calves exhibiting one or more of these signs were assigned a severity score of 1 (mild), 2

(moderate), 3 (severe), or 4 (moribund) and brought to the handling facility for further evaluation. Heifers assigned severity scores of 1 or 2 were treated with an antimicrobial if rectal temperature was ≥ 40°C, and heifers with severity scores of 3 or 4 were treated regardless of rectal temperature.

The treatment regimen for BRD consisted of three antimicrobials. Tulathromycin was considered the first antimicrobial treatment for MET heifers, and was also used as the first treatment for CON heifers. Heifers were not eligible for a second antimicrobial treatment until seven days after receiving tulathromycin, unless a severity score of 3 or 4 was assigned, in which case heifers were eligible for a second treatment after four days. The second antimicrobial used was enrofloxacin (Baytril, Bayer Animal Health, Shawnee Mission, KS; 10 mg/kg). After receiving this treatment, heifers were not eligible for the third antimicrobial until 48 hours later. The third treatment consisted of two doses of ceftiofur hydrochloride (Excenel, Pfizer Animal Health; 2.2 mg/kg) that were given 48 hours apart. All medications were administered following label directions. Tulathromycin was delivered in the left side of the neck, and all subsequent antimicrobial treatments were delivered in alternating sides of the neck.

Bronchoalveolar Lavage Sampling

Bronchoalveolar lavage samples were obtained from the 40 selected heifers on days 0, 4, 8 and 14. The minimum and maximum recommended post-treatment intervals for tulathromycin are eight and 14 days, respectively (Apley, 2006); therefore, sampling days were selected accordingly. Day 4 sampling period was selected to monitor for any changes in potential respiratory pathogens in BAL specimens.

At sampling, heifers were first restrained in a squeeze chute, haltered, and cross ties were used to position the head so that the heifer's nose was elevated. Then, samples were obtained by inserting a 240 cm-long BAL tube (Broncho-alveolar lavage equine catheter J639, Jorgensen Laboratories, Loveland, CO) equipped with a three-way stop cock into one of the nares. The BAL tube was passed into the trachea, past the tracheal bifurcation, into a distal lung lobe, and the area was sealed by inflating the cuff with approximately 8 to 10 mL of air. A 60-mL syringe containing 0.9% sterile saline solution was attached to the stopcock, which was then opened to allow instillation of the saline. Solution was immediately aspirated, and the process of instilling and aspirating was repeated two more times with fresh sterile solution each time, for a total of three aliquots of 60 mL each (total = 180 mL). Retrieval was typically 50 – 75% of the volume instilled. The third BAL specimen collected was submitted for culture if 20 mL or greater was obtained. If less than 20 mL of sample was collected, the second BAL fluid aliquot was combined with the third. Aliquots were placed in a cooler with either ice or an ice pack, and transported to the laboratory for bacterial and mycoplasma analysis.

At the laboratory, swabs from each BAL sample were streaked across a BBL Columbia sheep blood agar plate (Becton Dickinson, Sparks, MD) and a *Mycoplasma* agar plate (UC Davis Medical Services, Davis, CA). Plates were incubated at 37°C in 7% CO_2 for 24 hours for blood agar plates, and up to 10 days for mycoplasma plates. Colonies that grew on blood agar plates with morphology typical of BRD-causing organisms (*Mannheimia haemolytica*, *Pasteurella multocida*, *Arcanobacterium pyogenes*, and *Histophilus somni*) were isolated, and 3% H_2O_2 catalase and oxidase (Becton Dickinson, Franklin Lakes, NJ) tests were performed. If organisms reacted appropriately,

organisms were identified using the Sensititre™ GNID panel (Trek Diagnostic Systems, Cleveland, OH). Samples that grew colonies on *Mycoplasma* plates that were typical of *Mycoplasma* were considered to be positive for *Mycoplasma* spp.

Ruminal Temperature Monitoring

When calves arrived at WSBRC, temperature monitoring boluses reported current ruminal temperature to a remote computer at a mean rate of once every 3.3 minutes. Boluses first transmitted signals to fixed transceiver stations, which were specifically designed to receive bolus signals, located above the middle of each pen's feed bunk, above the middle of the rear fence line of each pen, and above each automatic water unit, which were located along the fence line and shared between adjacent pens. Data were then wirelessly relayed to a computer and logged in a database file.

Temperature data were evaluated for each heifer, and water drinking events were identified and removed from the data set prior to statistical analysis. The beginning of a drinking event was identified by a temperature decrease of at least 0.28°C from the previous measurement. The end of the water drinking event was identified when temperature either ceased to increase over a 10 minute time span, or increased to the last temperature observed prior to the drinking event. After removing water-associated temperatures from the data set, average and maximum daily temperatures were determined from 0700 to 0700 for each heifer.

Statistical Analysis

Bronchoalveolar lavage culture results were first summarized by pen, and percent of samples testing positive for all pathogenic specie within each pen were analyzed as response variables to the fixed effects of origin, treatment, day, and all interactions among the three. If a fixed effect was not significant, it was removed from the analysis. Ruminal temperature data were also analyzed with pen as the experimental unit, with the same fixed effects as those used for BAL results. Both analyses were conducted using the GLIMMIX procedure of SAS (SAS Institute; Cary, NC). Repeated measures were included using an autoregressive structure, with day as the repeated subject, and the random effect of pen within treatment. Performance data were analyzed using the MIXED procedure of SAS. The model used was the same as that for BAL and temperature results, with the exception that repeated measures were not included. For all analyses, Least squares means were calculated, and when means were different at the $P \leq 0.05$ level, means were separated using the PDIFF option. Differences are discussed when $P \leq 0.05$, and considered tendencies when $0.05 < P \leq 0.10$.

RESULTS

It was determined that no calves from either place of origin were persistently infected with bovine viral diarrhea virus. One CON heifer from LA and one CON heifer from KY were removed from the experiment on days 11 and 22, respectively, due to lameness. One CON heifer from KY was removed from the experiment on day 12 due to severe clinical BRD, and one CON heifer from LA died of cranioventral bronchopneumonia on day 27. All available data for these four heifers were included in

the analyses. The two heifers removed from the experiment prior to day 14 were not sampled on that day, and ruminal temperatures of these heifers were not included in the analysis after they were removed.

Frequency of treatment for BRD by origin and treatment is shown in Table 4.1, and timing of treatment of CON and MET heifers are shown in Figures 4.1 and 4.2, respectively. Overall morbidity incidence was very low for LA heifers, and very high for KY heifers. Two of the eight heifers originating from LA and exposed to the CON method experienced clinical BRD, one of which died of cranioventral bronchopneumonia 27 days after processing. Signs of clinical BRD were not observed in MET heifers from LA. Five of the eight CON heifers from KY experienced clinical BRD and received treatment, and nine of the 12 MET heifers from KY experienced clinical BRD and received additional treatment. A majority of first treatments occurred during the first ten days, but timing of all treatments was spread across 43 days.

Bronchoalveolar Lavage Cultures

Results for BAL samples obtained from LA heifers on day 8 were compromised and not included. Overall, incidence of potential pathogenic species in BAL samples of heifers originating from LA was low. Additionally, *Archanobacterium pyogenes* was only observed in one sample obtained from a MET heifer from LA on day 0, and from zero samples from heifers originating from KY; therefore, results for this pathogen are not presented. Only main effects are presented, as there were no interactions observed ($P > 0.05$).

The percentage of samples testing positive for *Pasteurella multocida* was affected ($P < 0.01$) by group, as 3.5% of samples from LA heifers tested positive for this microorganism, compared to 27.8% in heifers originating from KY (Figure 4.3). There was a tendency ($P = 0.08$) for treatment to affect incidence of *P. multocida*, with 16.0% of samples from CON heifers testing positive compared to 6.9% in samples from MET heifers (Figure 4.4). Day did not affect ($P = 0.20$) percent incidence of *P. multocida* (Figure 4.5).

Mannheimia haemolytica was not cultured from any heifers originating from LA; therefore, results for this pathogen are only presented for heifers originating from KY. Treatment did not affect ($P = 0.89$) percent of samples testing positive for *M. haemolytica* (Figure 4.6). There was a tendency ($P = 0.10$) for day to affect percent of samples testing positive for *M. haemolytica*, as 54.8% of samples contained the organism on day 0, compared to 20.4% on days 8 and 14 (Figure 4.7). Samples obtained on day 4 did not differ ($P \geq 0.14$) from those obtained on any other day of the experiment.

The percentage of samples containing *Mycoplasma* spp was affected by origin ($P < 0.01$), with 42.5% of samples from LA heifers testing positive, compared to 71.6% from KY heifers (Figure 4.8). However, there were no differences ($P \geq 0.67$) due to treatment or day (Figures 4.9 and 4.10, respectively).

Ruminal Temperatures

There was an origin × treatment × day interaction for ruminal temperature ($P < 0.01$, Figure 4.11). Upon arrival, heifers originating from KY had 0.80°C higher ($P < 0.01$) ruminal temperatures compared to those originating from LA. Generally, CON

heifers from KY had the highest ruminal temperature during the first five days, with average daily temperature exceeding 40.2°C. Conversely, average daily temperatures of MET heifers from LA remained lower than 40.0°C throughout the first 14 days.

Among heifers originating from LA, ruminal temperatures were not affected (P = 0.36) by treatment on day 1, but heifers receiving metaphylaxis had lower temperatures compared to CON on days 4, 7, 9, 10, and 14. Among heifers originating from KY, metaphylaxis reduced ruminal temperature by 0.71°C on day 1 and by 0.65°C on day 2 after processing compared to CON. However, beginning on day 3, ruminal temperatures of these heifers increased steadily, such that treatment did not affect (P > 0.10) ruminal temperature on any other day during the two weeks following processing.

Heifer Performance

There were no interactions ($P \geq 0.15$) between origin and treatment for heifer performance; therefore, only main effects are presented (Table 4.2). Arrival BW on day 0 was not different among origin or treatment groups ($P \geq 0.73$). Bodyweights were also unaffected by origin on any other day of the 56-day receiving phase ($P \geq 0.13$). Average daily gain (ADG) was unaffected by origin during the first two 14-d periods. Heifers from LA gained 1.07 kg/day more (P < 0.01) from days 28 to 42, and 0.89 kg/day less (P < 0.01) from days 42 to 56 compared to heifers from KY. Overall performance during the entire 56-day receiving phase was not different (P = 0.81) between the two places of origin.

Use of metaphylaxis resulted in 17.5 kg greater (P = 0.01) BW on day 14, 18.7 kg greater (P = 0.04) BW on day 28, tended (P = 0.08) to increase BW by 13.4 kg on day

42, and increased ($P = 0.04$) BW by 14.6 kg at the end of the receiving phase on day 56. However, the only period when metaphylaxis affected ADG was the first 14 day period, where MET heifers gained 1.02 kg/day more ($P = 0.02$) compared to CON. Gains were not different ($P \geq 0.38$) between the two treatments during all other 14-day periods. Due to differences during the first 14 days, overall ADG across the entire 56-day receiving phase tended ($P = 0.07$) to be 0.21 kg/day greater in MET heifers compared to CON.

DISCUSSION

Bovine respiratory disease is a multifactorial disease involving viruses, bacteria, and various stressors. Calves from certain geographic regions are generally considered to be more susceptible to BRD than others. These regions include most of the states in the southeast, including Kentucky and Louisiana. One possible explanation for this difference is that herd sizes are generally smaller in these states, leading to greater levels of commingling prior to entry into the feedlot (Thomson and White, 2006). Louisiana has an average herd size of 65, and average number of calves sold per farm is 23 (NASS, 2007b), while Kentucky has an average beef herd size of 53, and average number of beef calves sold per farm is only 17 (NASS, 2007a). At the LA purchase facility calves arrived in very small lots, with no more than 10 calves per lot. Information on arrival lot size at the Kentucky facility was unknown. Therefore, commingling in both groups of heifers was probably extensive and differences due to origin may likely be related to other factors.

When accounting for the distance traveled from the purchase location to the gathering location, the distance traveled by KY heifers was nearly 500 km longer

compared to the LA heifers. Increased travel time has been associated with greater morbidity, which can be attributed to longer periods of feed and water deprivation (Pinchak et al., 2004; Cole and Hutcheson, 1985). However, some researchers have not identified an association between distance traveled and calf mortality (Ribble et al., 1996). While the literature presents conflicting results, one must still use some level of subjectivity when observing calves arriving at the feedlot. If it appears that the long distance has caused great shrinkage, hence dehydration, calves must be managed appropriately. Water and palatable feed should be made available immediately to minimize the ongoing effects of transportation stress due to nutrient deprivation. While calves from both LA and KY appeared stressed on arrival by evidence of walking the pen perimeter and bawling, the added distance for the KY heifers may have contributed to the greater incidence of morbidity in these calves.

Calves arriving from LA were delivered to WSBRC in late May of 2009, while calves arriving from KY were delivered in mid-September of 2009. While place of origin effect was investigated, season may also be a factor when interpreting these results. The number of calves sold through market channels peaks during late October, which nearly coincides with the time of greatest risk for calves to contract a fatal case of BRD in mid-November (Ribble et al., 1996). Therefore, it was noted that it is difficult to discern whether BRD-related fatalities during this time are related to weather or to increased disease exposure, or yet other undetermined factors. If increased exposure is considered to be the likely cause of this greater risk, calves marketed in September would be at greater risk compared to those marketed in May. As calves arriving from LA in May had fewer BRD-causing pathogens present in the lung lavage fluid and generally

lower body temperatures, it is interpreted that these calves were at lower risk compared to the KY heifers arriving in September.

Breed type may have also contributed to differences due to origin, as heifers originating from LA were phenotypically influenced by *Bos indicus* breeding and heifers originating from KY were phenotypically of British breed type. As a general rule, cattle of *Bos indicus* breeding are more resistant to disease than those of *Bos taurus* breeding (Turner, 1980). It has been reported that incidence of BRD in mixed breed cattle with Tropical × British crossbreeding is lower than that of calves with British × British crossbreeding (Snowder et al., 2005). The apparent *Bos indicus* genetic breed influence in the LA heifers is a possible contributor to the lower incidence in morbidity of these heifers.

Percent of samples with *P. multocida* and *Mycoplasma* spp present was similar to that observed by others, where nasal swab samples from calves not receiving metaphylactic treatment contained *P. multocida* 26.5% of the time, and *Mycoplasma* spp 54.4% of the time (Kilgore et al., 2005). However, in the present experiment, incidence of *M. haemolytica* was lower than that observed by Kilgore et al, where samples from affected calves contained the organism 63.3% of the time. Calves sampled in that study had been diagnosed with clinical BRD, whereas calves in the present experiment were not necessarily demonstrating signs of the illness at the time of sampling. It should be noted that while *M. haemolytica* was not isolated in samples from the 20 LA heifers, presence of the species was observed in 31% of samples obtained from LA heifers not assigned to the present experiment (data not presented). While some researchers have concluded that organisms isolated from nasal swab samples were identical to

transtracheal samples 70% of the time (DeRosa et al., 2000), others observed only moderate agreement between cultures from the nasopharyngeal region with BAL samples (Allen et al., 1991). Therefore, it is necessary to consider the potential differences in organisms isolated from the lower respiratory tract compared to the upper respiratory tract.

When interpreting results for *Mycoplasma* spp, it should be noted that microorganisms isolated from BAL samples were not speciated specifically for *M. bovis*. Therefore, the percent of samples presumably containing *Mycoplasma bovis* is likely less than the total isolates in this experiment. However, it is still notable that differences were not observed due to treatment or day, yet samples from LA heifers contained the organism less frequently than samples from KY heifers. This could imply that use of metaphylaxis may not have decreased the overall population of *Mycoplasma* spp, and that overall prevalence of *Mycoplasma* spp did not change during the first 14 days after processing. However, performance was also improved in heifers administered metaphylaxis at processing.

Reduced performance observed in KY heifers from days 28-42 compared to LA heifers may reflect the greater incidence of disease in those originating from KY. However, poor performance of LA heifers from days 42-56 is attributed to a period of extremely hot environmental conditions, and was not reflective of health status of the animals. A meta-analysis determined the use of metaphylaxis increased ADG of feedlot calves by 0.11 kg/day compared to calves not receiving metaphylaxis (Wileman et al., 2009). Calves receiving metaphylaxis in the present experiment had even greater improvements in ADG during the first 14 days, and tended to have 0.21 kg/day greater

ADG compared to CON over the first 56 days. The increased response to metaphylaxis in these calves could be due to greater risk for clinical BRD, particularly in the KY heifers, thereby increasing the potential for metaphylaxis to improve calf well-being.

Rectal temperatures of calves treated with tulathromycin has been shown to be lower than that of calves injected with saline for up to nine days following *M. bovis* challenge (Godinho et al., 2005). Also in that study, the overall presence of *P. multocida* and *M. haemolytica* cultured from nasal and lung lavage samples was low. These results are similar to the response in ruminal temperature observed in our study for the LA heifers, where metaphylaxis resulted in lower temperatures for 14 days, and where presence of bacterial species in lung lavage samples was also low. However, ruminal temperatures of MET heifers from KY decreased for only two days following metaphylaxis compared to CON heifers from KY; thereafter, ruminal temperatures of MET heifers were not different from CON. This temperature difference could be indicative of the greater incidence of *P. multocida* and *M. haemolytica* in KY heifers. While it may be expected that temperatures of calves at greater risk would respond more dramatically to metaphylaxis compared to those that are at lower risk, the combined stressors present in KY heifers likely contributed to the short two-day window of response in ruminal temperature after processing.

Metaphylaxis should be targeted to those calves that are at high risk of experiencing BRD. Heifers originating from LA would be considered high-risk, and the response to metaphylaxis in these heifers would have been anticipated to be positive. It is interesting to note that very few BRD-causing organisms were isolated in the BAL samples of LA heifers in both treatment groups. If more potential respiratory pathogens

would have been isolated from BAL samples, higher BRD morbidity and differences between the treatment groups may have been observed. Ruminal temperature response to metaphylaxis also showed differing results due to origin, as temperatures of MET heifers from LA remained lower than CON throughout most of the 14-day recommended maximum post-metaphylactic or post-treatment interval. In the high-risk calves from KY, temperatures of MET heifers were lower than CON for only the first two days after metaphylaxis. This temperature difference may indicate that a 14-day post-treatment interval is more warranted in lower-risk calves, but a shorter interval may be considered for high-risk calves. Additional research is needed to fully understand the changes occurring in respiratory pathogens present in the upper and lower respiratory tract of calves in response to metaphylaxis.

LITERATURE CITED

Allen, J. W., L. Viel, K. G. Bateman, S. Rosendal, P. E. Shewen, and P. Physick-Sheard. 1991. The microbial flora of the respiratory tract in feedlot calves: Associations between nasopharyngeal and bronchoalveolar lavage cultures. Can. J. Vet. Res. 55:341-346.

Apley, M. 2006. Bovine respiratory disease: Pathogenesis, clinical signs, and treatment in lightweight calves. Vet. Clin. Food. Anim. 22:399-411.

Bewley, J. M., M. E. Einstein, M. W. Grott, and M. M. Schutz. 2006. Comparison of reticular and rectal core body temperatures in lactating dairy cows. J. Dairy. Sci. 91:4661-4672.

Chirase, N. K., and L. W. Greene. 2000. Influence of oral natural interferon-alpha on performance and rectal temperature of newly received beef steers, in Proceedings. Western Section Am. Soc. Anim. Sci. 51:411-414.

Cole, N. A., and D. P. Hutcheson. 1985. Influence of prefast feed intake on recovery from feed and water deprivation by steers. J. Anim. Sci. 60:772-780.

DeRosa, D. C., G. D. Mechor, J. J. Staats, M. M. Chengappa, and T. R. Shryock. 2000. Comparison of *Pasteurella* spp. simultaneously isolated from nasal and transtracheal swabs from cattle with clinical signs of bovine respiratory disease. J. Clin. Microbiol. 38:327-332.

Duff, G. C., and M. L. Galyean. 2007. BOARD-INVITED REVIEW: Recent advances in management of highly stressed, newly received feedlot cattle. J. Anim. Sci. 85:823-840.

Godinho, K. S., A. Rae, G. D. Windsor, N. Tilt, T. G. Rowan, and S. J. Sunderland. 2005. Efficacy of tulathromycin in the treatment of bovine respiratory disease associated with induced *Mycoplasma bovis* infections in young dairy calves. Vet. Ther. 6:96-112.

Jim, G. K., C. W. Booker, C. S. Ribble, P. T. Guichon, and B. E. Thorlakson. 1999. A comparison of florfenicol and tilmicosin for the treatment of undifferentiated fever in feedlot calves in western Canada. Can. Vet. J. 40:179-184.

Kilgore, W. R., M. S. Spensley, F. Sun, R. G. Nutsch, K. A. Rooney, and T. L. Skogerboe. 2005. Clinical effectiveness of tulathromycin, a novel triamilide antimicrobial, for the control of respiratory disease in cattle at high risk for developing bovine respiratory disease. Vet. Ther. 6:136-142.

National Agricultural Statistics Service. 2006. Cattle death loss. Available at: http://usda.mannlib.cornell.edu/usda/current/CattDeath/CattDeath-05-05-2006.pdf. Accessed March 27, 2010.

National Agricultural Statistics Service. 2007a. Census of Agriculture – State Data, Kentucky. Table 16. Beef cow herd size by inventory and sales: 2007. Available at: http://www.agcensus.usda.gov/Publications/2007/Full_Report/Volume_1,_Chapter_1_State_Level/Kentucky/st21_1_014_016.pdf. Accessed March 15, 2011.

National Agricultural Statistics Service. 2007b. Census of Agriculture – State Data, Louisiana. Table 16. Beef cow herd size by inventory and sales: 2007. Available at:

http://www.agcensus.usda.gov/Publications/2007/Full_Report/Volume_1,_Chapter_1_State_Lev el/Louisiana/st22_1_014_016.pdf. Accessed March 15, 2011.

Pinchak, W. E., D. R. Tolleson, M. McCloy, L. J. Hunt, R. J. Gill, R. J. Ansley, and S. J. Bevers. 2004. Morbidity effects on productivity and profitability of stocker cattle grazing in the Southern Plains. J. Anim. Sci. 82:2773-2779.

Ribble, C. S., A. H. Meek, E. D. Janzen, P. T. Guichon, and G. K. Jim. 1996. Effect of time of year, weather, and pattern of auction market sales on fatal fibrinous pneumonia (shipping fever) in calves in a large feedlot in Alberta (1985-1988). Can. J. Vet. Res. 59:167-172.

Sims, L. E., T. K. Dye-Rose, C. L. Goad, B. P. Holland, L. O. Burciaga-Robles, D. L. Step, C. R. Krehbiel, and C. J. Richards. 2009. Use of rumen temperature for health monitoring in cattle. J. Anim. Sci. 87(E-Suppl 2):120. (Abstr.)

Snowder, G. D., L. D. Van Vleck, L. V. Cundiff, and G. L. Bennett. 2005. Influence of breed, heterozygosity, and disease incidence on estimates of variance components of respiratory disease in preweaned beef calves. J. Anim. Sci. 83:1247-1261.

Thomson, D. U., and B. J. White. 2006. Backgrounding beef cattle. Vet. Clin. Food Anim. 22:373-398.

Turner, J.W. 1980. Genetic and biologic aspects of Zebu adaptability. J. Anim. Sci. 50:1201-1205.

Wileman, B. W., D. U. Thomson, C. D. Reinhardt, and D. G. Renter. 2009. Analysis of modern technologies commonly used in beef cattle production: Conventional beef production versus nonconventional production using meta-analysis. J. Anim. Sci. 87:3418-326.

Table 4.1. Number of cases of morbidity and mortality of heifers originating from LA or KY and managed with the standard feedlot protocol (CON) or administered a metaphylactic dose of tulathromycin on arrival (MET)

	LA		KY	
Item	CON	MET	CON	MET
n	8	12	8	12
Frequency of treatment for BRD[1]				
Never treated	6	12	2	3
Treated once	1	0	2	2
Treated twice	0	0	3	7
Treated three times	0	-	1	-
Mortality, n	1	0	0	0

[1]MET heifers never treated only received metaphylactic dose, and were not eligible for a third additional antimicrobial dose.

Table 4.2. Performance of feedlot heifers originating from LA or KY and managed with standard feedlot protocol (CON) or administered a metaphylactic dose of tulathromycin on arrival (MET)

	Origin				Treatment			
Item[1]	LA	KY	SEM	*P*-Value	CON	MET	SEM	*P*-Value
n	20	20			16	24		
BW, kg								
d 0	248.0	246.0	20.3	0.76	245.8	248.1	20.4	0.73
d 14	255.9	263.0	20.5	0.28	250.7	268.2	20.6	0.01
d 28	275.5	277.8	18.1	0.78	267.3	286.0	18.2	0.04
d 42	304.5	292.8	22.9	0.13	292.0	305.4	23.1	0.09
d 56	306.4	306.6	21.0	0.98	299.2	313.8	21.1	0.04
ADG, kg								
d 0-14	0.64	1.22	0.26	0.13	0.42	1.44	0.28	0.02
d 14-28	1.37	1.06	0.27	0.41	1.16	1.27	0.28	0.77
d 28-42	2.06	0.99	0.37	<0.01	1.67	1.38	0.39	0.38
d 42-56	0.13	1.02	0.18	<0.01	0.56	0.60	0.19	0.84
d 0-56	1.06	1.08	0.08	0.81	0.96	1.17	0.09	0.07

[1]BW = body weight, ADG = average daily gain.

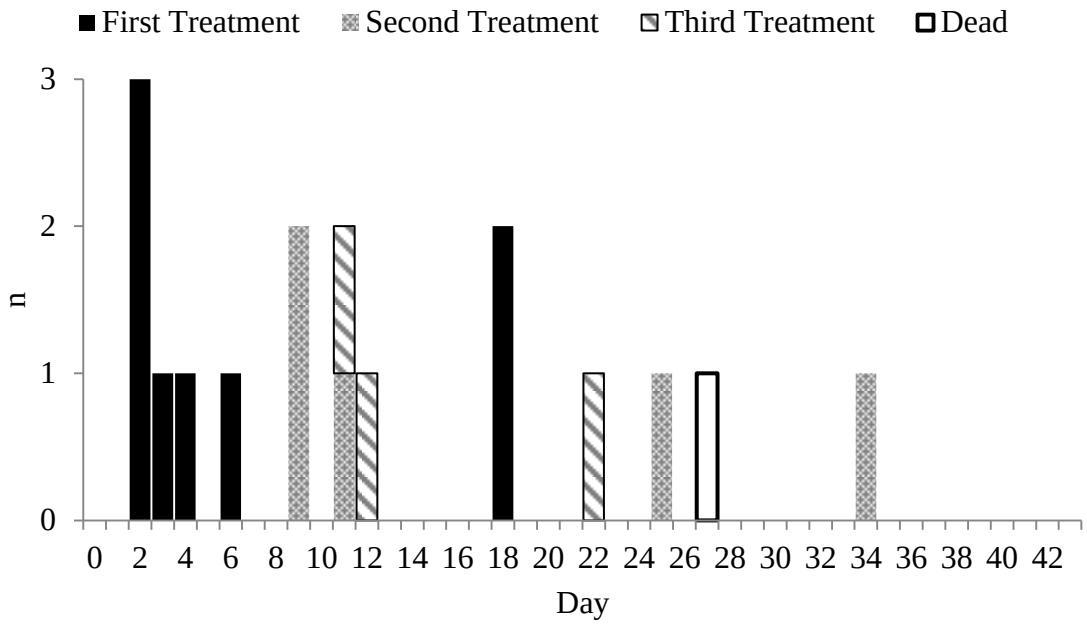

Figure 4.1. Timing of treatment for BRD of heifers managed with the standard feedlot protocol (CON). For the heifer that died on day 27, antimicrobial treatments administered prior to mortality are included.

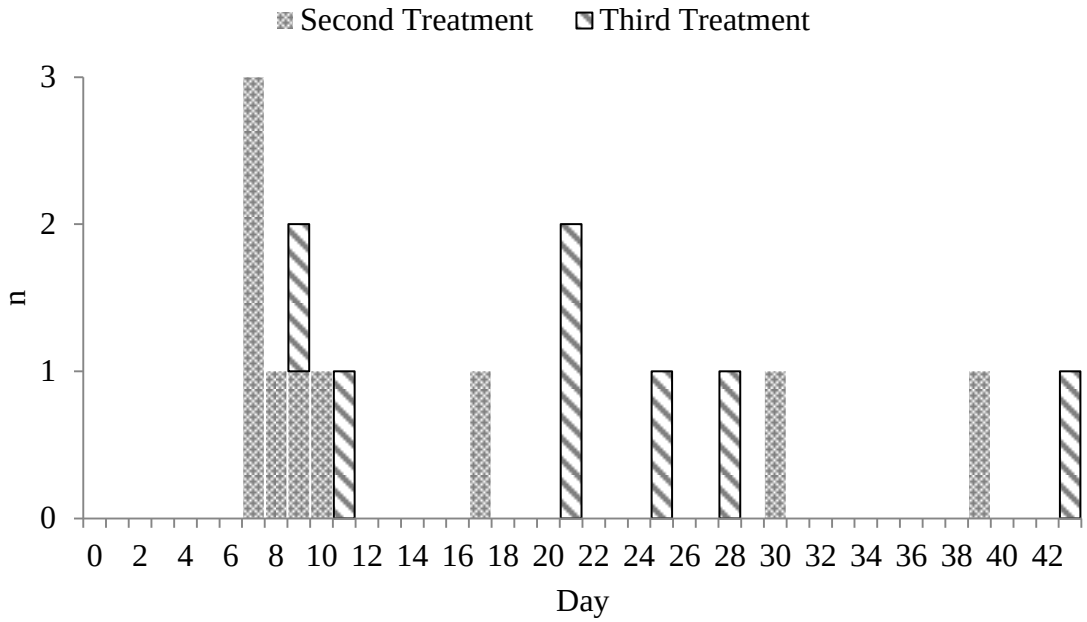

Figure 4.2. Timing of treatment for BRD of heifers administered a metaphylactic dose of tulathromycin at processing (MET).

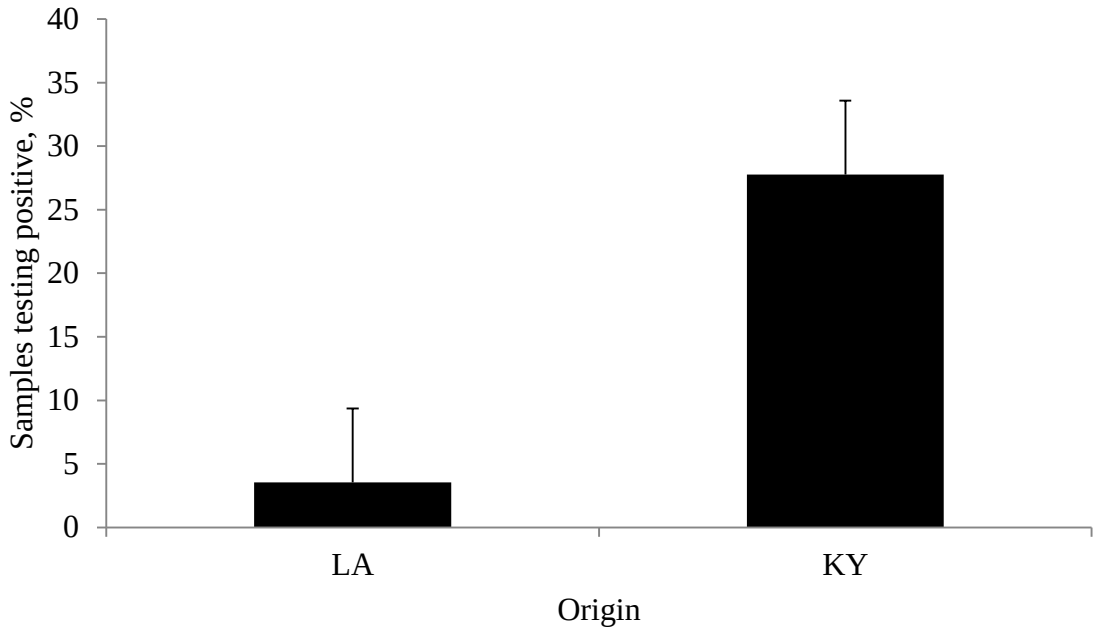

Figure 4.3. Percent of bronchoalveolar lavage samples testing positive for *Pasteurella multocida* in heifers originating from LA or KY, n = 40. Origin effect: $P < 0.01$.

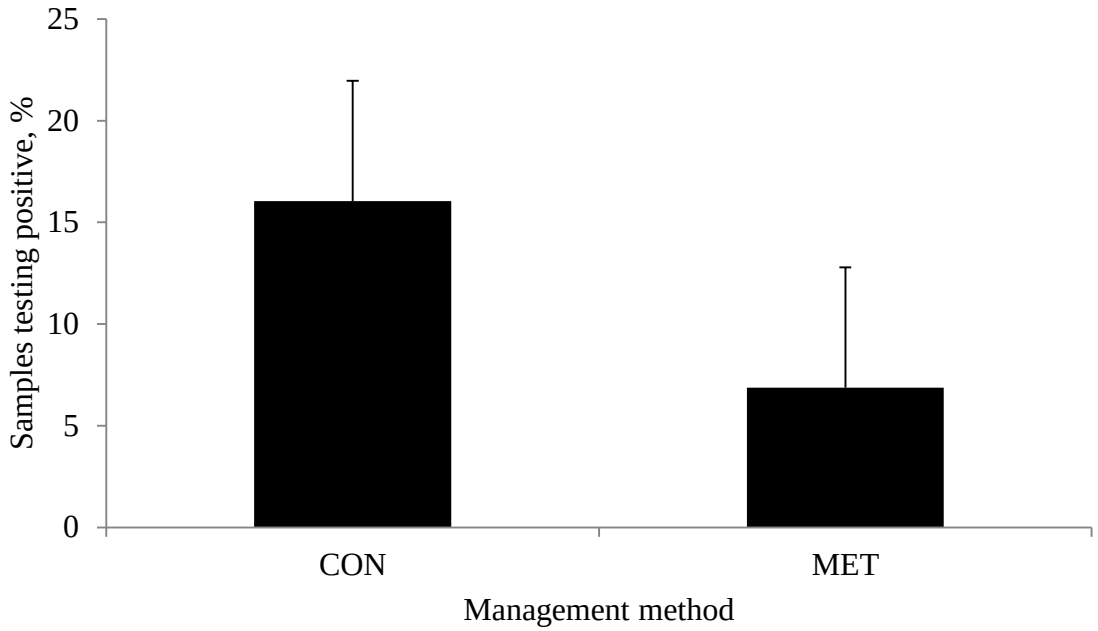

Figure 4.4. Percent of bronchoalveolar lavage samples testing positive for *Pasteurella multocida* in heifers managed with standard feedlot protocol (CON) or administered a metaphylactic dose of tulathromycin at processing (MET), n = 40. Treatment effect: P = 0.08.

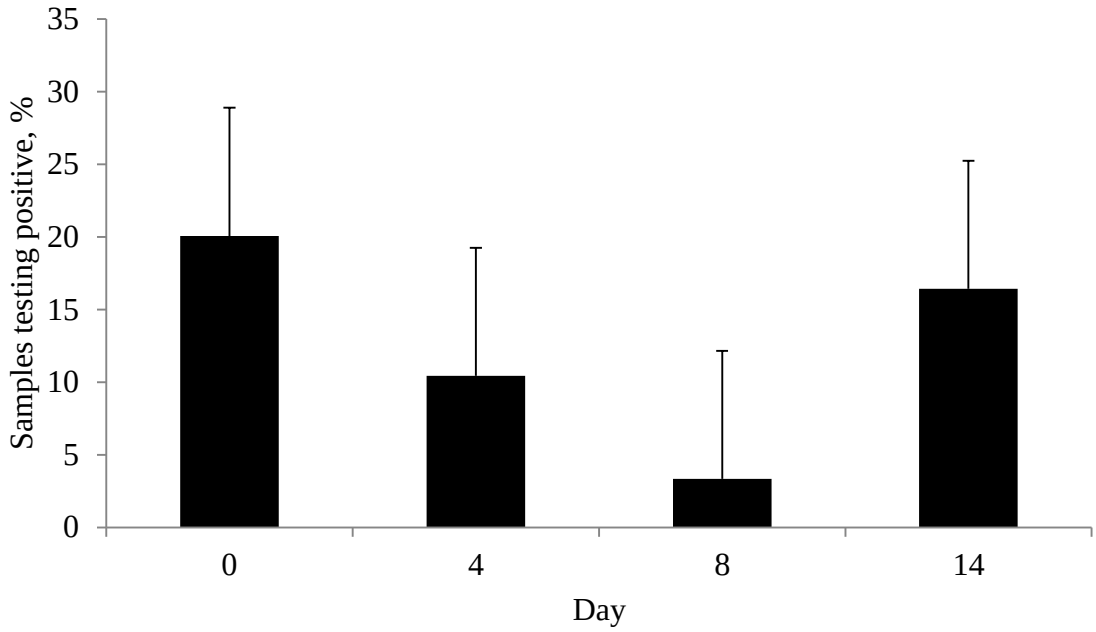

Figure 4.5. Percent of bronchoalveolar lavage samples testing positive for *Pasteurella multocida* in heifers on days 0, 4, 8, and 14 after processing, n = 40. Day effect: P = 0.20.

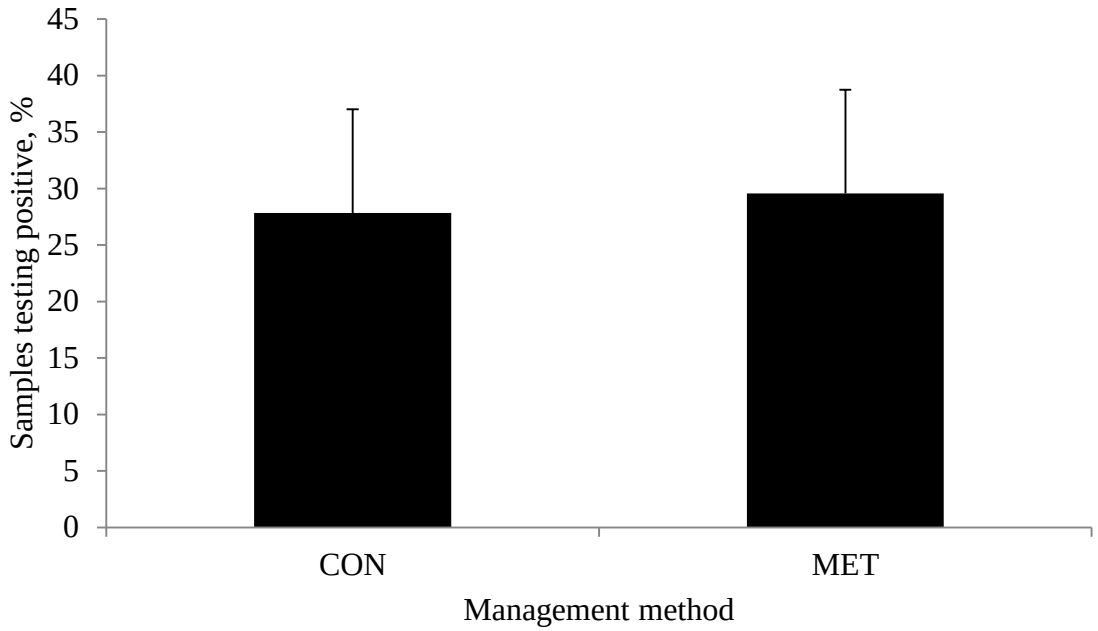

Figure 4.6. Percent of bronchoalveolar lavage samples testing positive for *Mannheimia haemolytica* in heifers originating from KY and managed with the standard feedlot protocol (CON) or administered a metaphylactic dose of tulathromycin at processing (MET), n = 20. Treatment effect: $P = 0.89$.

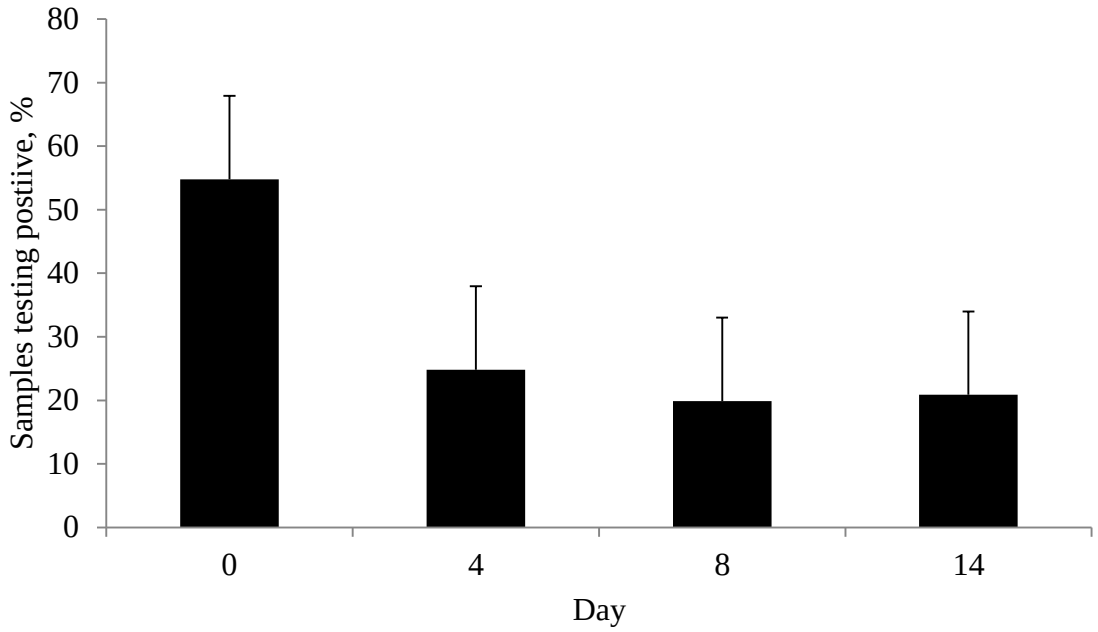

Figure 4.7. Percent of bronchoalveolar lavage samples testing positive for *Mannheimia haemolytica* in heifers originating from KY on days 0, 4, 8, and 14 after processing, n = 20. Day effect: $P = 0.10$.

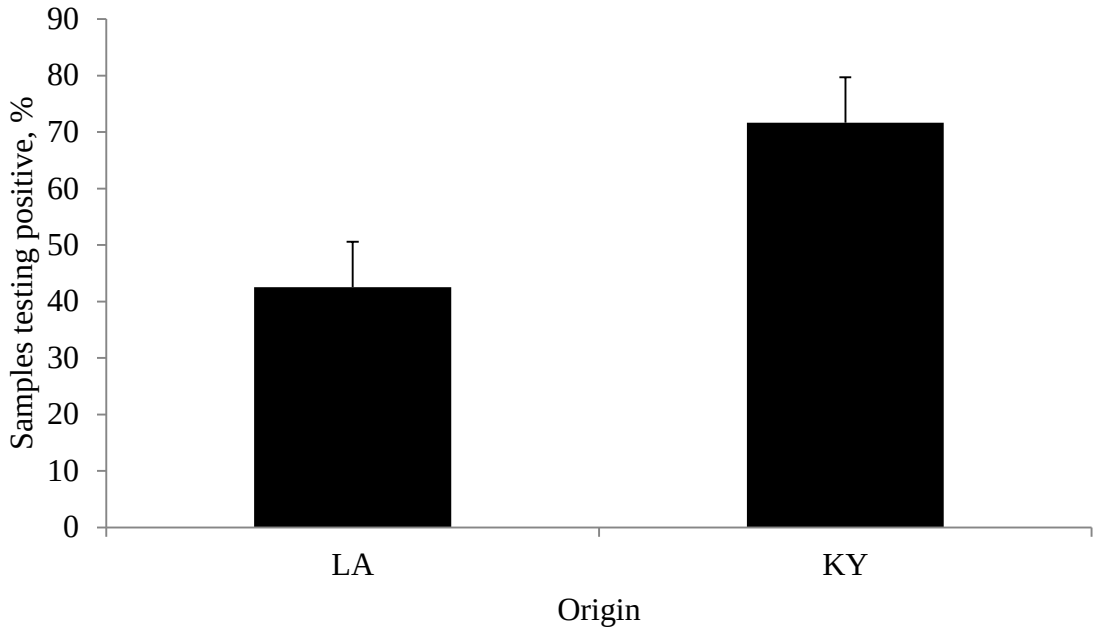

Figure 4.8. Percent of bronchoalveolar lavage samples testing positive for *Mycoplasma* spp in heifers originating from LA or KY, n = 40. Origin effect: $P < 0.01$.

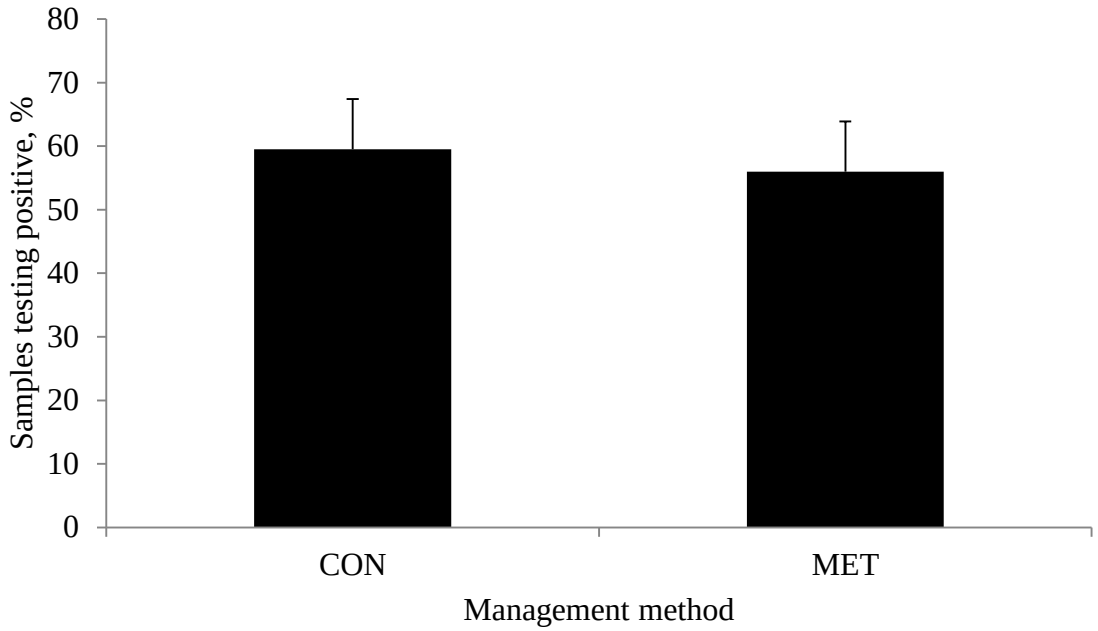

Figure 4.9. Percent of bronchoalveolar lavage samples testing positive for *Mycoplasma* spp in heifers managed with the standard feedlot protocol (CON) or administered a metaphylactic dose of tulathromycin at processing (MET), n = 40. Treatment effect: P = 0.73.

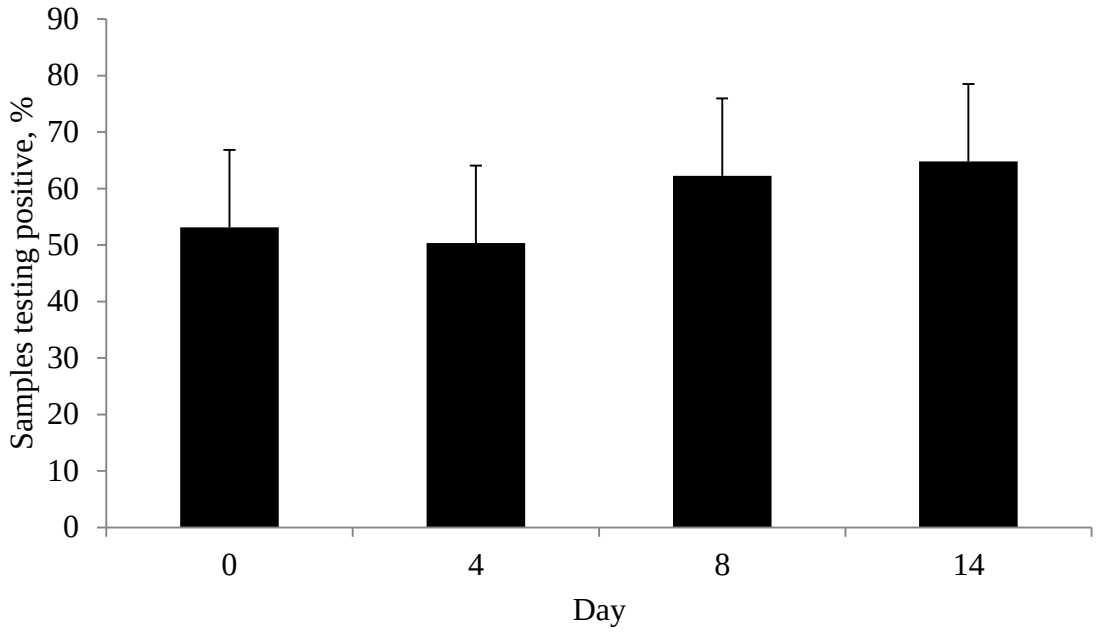

Figure 4.10. Percent of bronchoalveolar lavage samples testing positive for *Mycoplasma* spp in heifers on days 0, 4, 8, and 14 after processing, n = 40. Day effect: $P = 0.67$.

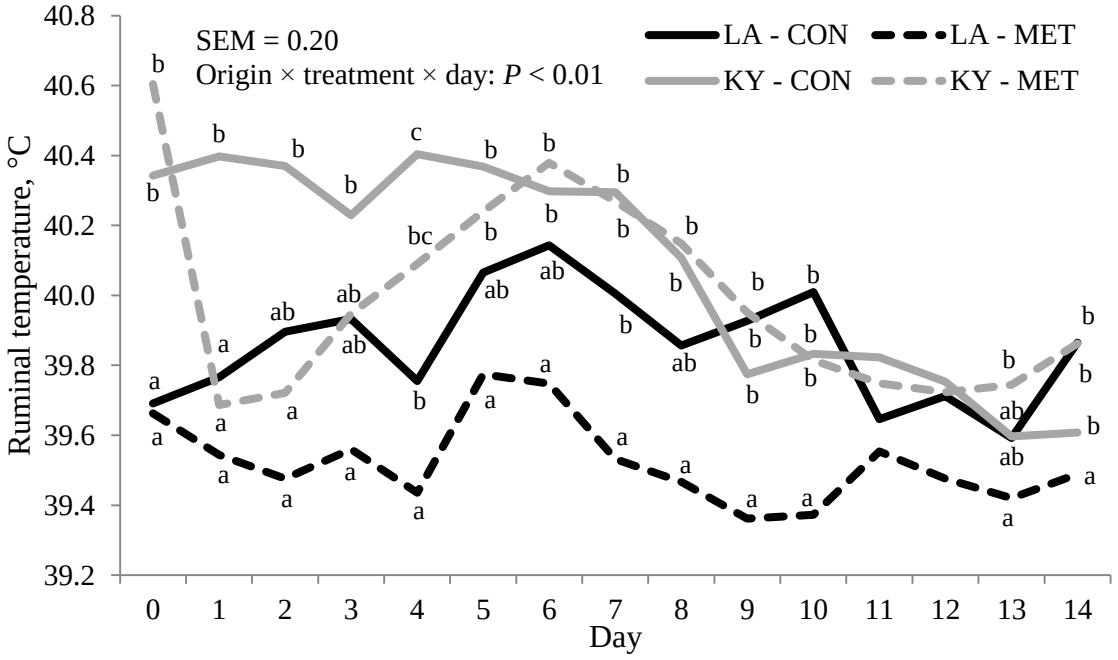

Figure 4.11. Ruminal temperature of heifers originating from LA or KY and managed with the standard feedlot protocol (CON) or administered a metaphylactic dose of tulathromycin at processing (MET), n=40. Means within a day without a common label differ ($P < 0.05$).

CHAPTER V

IMPACT OF TRUCK COMPARTMENT ON RUMINAL TEMPERATURE DURING TRANSIT, HEALTH, AND PERFORMANCE OF COMMINGLED BEEF HEIFERS

ABSTRACT

This experiment determined how truck compartment affects ruminal temperature during transit and subsequent performance and morbidity of calves, and if temperature during transit may predict subsequent health and performance. Four truckloads of heifers (n = 328) were delivered, and compartment in which heifers were housed was recorded upon arrival. Main effects included level [bottom (**BD**), upper (**UD**) decks] and section [nose (**N**), middle (**M**), rear (**R**)] of the truck. Ruminal temperature showed a level × section interaction ($P < 0.01$). For heifers in the BD, temperatures were greatest ($P < 0.05$) in the nose. For heifers in the UD, temperatures were greatest ($P < 0.05$) in the middle. Heifers in the UDR had the lowest temperatures ($P < 0.05$). From day 0 to 14, ADG showed a level × section interaction ($P = 0.02$). Among UD heifers, those in the nose gained 0.63 kg/day less ($P < 0.05$) compared to the middle, whereas ADG was not affected by section for heifers in the BD ($P > 0.10$). Morbidity measurements of heifers showed level × section interactions ($P \leq 0.02$). Within the first 14 days, heifers in the BDN and UDR were treated for BRD more often ($P \leq 0.05$) than heifers in the BDR and

UDN. Regression analysis did not suggest a relationship ($P \geq 0.12$) between ruminal temperatures during trucking and subsequent health. Results indicate that ruminal temperature and treatment frequency are affected by truck compartment during transit, but transport temperatures are not effective predictors of subsequent health or performance.

KEY WORDS: Beef cattle, body temperature, health, performance, transportation

INTRODUCTION

Bovine respiratory disease (**BRD**) is the most economically significant disease observed in feedlot cattle in the U.S (Griffin, 1997; NASS, 2006). Calves at greatest risk for contracting BRD are those that are subjected to a series of stressors such as commingling and shipping long distances immediately following weaning. Not all cases of BRD are detected, as indicated by presence of lung lesions in cattle at harvest (Bryant et al., 1999; Buhman et al., 2000; Wittum et al., 1996). Identifying management practices that increase risk and novel methods of BRD detection may improve health, well-being and economics of feedlot cattle.

There is potential for ruminal temperature monitoring to aid in the detection of BRD. Ruminal temperatures of beef steers increased in response to challenge with *Mannheimia haemolytica* and bovine viral diarrhea virus (Rose-Dye et al., 2011). In calves naturally infected with BRD, Sims et al., (2009) observed that average ruminal temperature was greater with increased antimicrobial treatments required to treat the disease and decreased ADG.

White et al. (2009) compared performance of newly received feedlot calves based on the area of the truck in which the calves were housed during transit. Calves traveling in the top rear compartment had lower gains from arrival through revaccination compared to those in the other sections, and those in the middle compartments were more likely to be treated for BRD. The authors called for additional research to investigate potential causes for these differences. The objectives of this experiment were: 1) to determine how area of the truck during transit affects ruminal temperature during transit and subsequent health and performance of recently weaned beef calves, and 2) determine if ruminal temperature during transit may be used as a predictor of future calf health and performance.

MATERIALS AND METHODS

All procedures were approved by Oklahoma State University's Animal Care and Use Committee. This experiment was conducted using 4 truckloads of newly weaned heifer calves. In May 2009, 148 calves (BW = 248.6 ± 39.1 kg) were commingled at a buying station in Baton Rouge, LA. In September 2009, 180 calves (BW = 237.4 ± 20.4 kg) were purchased in Lexington, KY and commingled at the livestock market in Hillsboro, OH. Prior to transport, calves received a unique identification ear tag and a remote ruminal temperature monitoring bolus (Strategic Solutions International, LLC; Stillwater, OK). Within each purchase group, calves were loaded onto 2 semi trailers. Calves were shipped to the Willard Sparks Beef Research Center in Stillwater, OK (1,112 km from the LA location and 1,424 km from the OH location). For both groups of calves the time in transit was approximately 14 h and arrival was at approximately 0600.

Boluses wirelessly transmitted temperature information every 2 min to data logging transceivers mounted in multiple locations throughout the trailers. Transceiver stations then reported bolus data wirelessly to a transceiver capable of storing data from the trip until it was downloaded to a database file upon arrival at the research feedlot.

Figure 5.1 depicts the areas of trucks. Compartments included the bottom deck nose (**BDN**), middle (**BDM**), and rear (**BDR**), and the upper deck nose (**UDN**), middle (**UDM**), and rear (**UDR**). One load of calves from the first lot did not fill a complete load, and heifers used in the experiment were only housed in the UDM and BDM sections. Upon arrival heifers were unloaded by compartment and allowed to rest for at least 1 h. Calves remained separated in their truck compartment group during this time. Calves were then weighed, area of the truck was recorded, and they were placed in pens with free access to grass hay and water until initial processing 48 to 72 h later.

At initial processing, calves received a clostridial vaccine (Vision 7 with Spur, Intervet/Schering-Plough, DeSoto, KS), a deworming treatment (Ivomec Plus Injectable, Merial, Duluth, GA), and were dehorned when necessary. Heifers also received a viral pathogen vaccine. Those purchased at the LA location received Vista 5 SQ (Intervet/Schering-Plough, DeSoto, KS) at initial processing and Express 5 (Boehringer Ingelheim, St. Joseph, MO) 14 days later. Those purchased at the OH location received Express 5 at initial processing and 14 days later. As part of a separate experimental protocol initiated upon processing, calves were blocked by BW, stratified by coat color, and randomly sorted into 24 pens. One third of the pens were assigned to a protocol with metaphylactic antimicrobial administered at processing. Any calves assigned to these pens received tulathromycin (2.5 mg/kg BW, Draxxin, Pfizer Animal Health, Exaton,

NY) at processing. This represented 47 of the calves originating in LA and 56 calves arriving from OH. Percentage of calves administered metaphylaxis was not different (P = 0.49, data not shown) among truck compartments. Heifers were maintained on a 63% concentrate ration containing 22 mg/kg of monensin (Rumensin 80, Elanco Animal Health, Indianapolis, IN).

Each morning, heifers were individually observed for clinical signs consistent with BRD by trained individuals. Signs included depression, lack of fill compared to pen mates, altered gait, and nasal or ocular discharge. Calves exhibiting 1 or more signs were assigned a severity score of 1 (mild) to 4 (moribund). These calves were brought to the handling facilities for further evaluation and measurement of rectal temperature. Heifers received an antimicrobial when rectal temperature was ≥ 40.0°C for severity scores of 1 and 2, or regardless of rectal temperature for severity scores of 3 or 4.

The antimicrobial treatment protocol for all calves was tulathromycin, enrofloxacin (10 mg/kg BW, Baytril, Bayer Animal Health, Shawnee Mission, KS), and ceftiofur-HCl (2.2 mg/kg BW, Excenel, Pfizer Animal Health) approximately 48 h apart. For calves that received a metaphylactic dose of tulathromycin, enrofloxacin was administered the first time they were identified with BRD by the protocol above. All antimicrobial injections were delivered subcutaneously, with tulathromycin being administered on the left side of the neck, and all subsequent injections administered on alternating sides of the neck.

Temperature data were examined for each heifer, and heifers with less than 50 observations were omitted from the analysis. A total of 297 heifers were included in the analysis, and the mean number of observations per heifer was 347. Temperature data

were analyzed using the GLIMMIX procedure of SAS (SAS Institute, Cary, NC). Temperatures were first summarized by h for each heifer, and h was included as a repeated measure in an autoregressive structure. Percent of heifers receiving treatment for BRD and the percentage that were treated within the first 14 days were analyzed using the GLIMMIX procedure of SAS. Performance data were analyzed using the MIXED procedure of SAS. For all analyses, main effects included level (UD, BD) and section (N, M, R) and the interaction between level and section. Random effects included purchase group, truck, and heifer within level and section of the trailer. As heifers were not allocated to level and section based on BW, initial BW was included as a covariate for all subsequent BW analyses. Least squares means were calculated, and pairwise means separations were performed using the PDIFF option when means were different at the $P \leq 0.05$ level. Differences are discussed when $P \leq 0.05$, and are considered tendencies when $0.05 < P \leq 0.10$.

To determine if ruminal temperature may be used to predict calf health and performance, the REG procedure of SAS was used. Dependent variables included ADG from day 0 to 14, from day 0 to 28, and from day 0 to 56; and date of first and second treatments for BRD. The regressor was mean calculated ruminal temperature from the duration of transit.

RESULTS AND DISCUSSION

Body temperatures of heifers showed a level × section interaction ($P < 0.01$, Table 5.1). Temperatures of heifers housed in the nose sections were 0.21°C greater ($P = 0.01$) for those on the bottom deck compared to the upper deck. Temperatures of heifers

housed in the middle sections were not different ($P = 0.94$) between the 2 levels. Among heifers housed in the rear sections, temperatures were 0.29°C greater ($P < 0.01$) in heifers on the bottom deck compared to the upper deck. Of heifers housed in the bottom deck, mean temperatures of heifers housed in the nose tended ($P = 0.09$) to be 0.12° greater than temperatures of heifers housed in the middle, whereas temperatures of heifers in the BDR did not differ ($P \geq 0.18$) from the other 2 bottom deck sections. Of heifers housed in the upper deck, mean ruminal temperatures were 0.23°C lower ($P \leq 0.05$) in the UDR compared to the UDM and UDN, which were not different ($P = 0.18$). The heifers housed in the UDR exhibited the lowest ruminal temperatures, whereas the heifers housed in the BDN had the highest ruminal temperatures ($P < 0.01$).

Differences in ruminal temperatures could partly be attributed to varying levels of air circulation among the compartments. Although air flow and gases were not measured, it is assumed that air quality is improved in the upper deck compared to the bottom, and that air quality improves when moving from the nose to the rear. Mean temperatures of the heifers housed in the BDN may have been greatest due to lack of air circulation in this compartment. Likewise, the compartment with the greatest potential for increased air circulation is the UDR, the compartment that resulted in lowest mean ruminal temperatures. Heifers housed in the bottom deck nose and rear generally exhibited increased temperatures compared to their counterparts in the upper deck. Temperatures in the upper deck sections present an inconsistency, as heifers in the UDN had lower temperatures compared to the UDM. Therefore, differences in temperatures do not appear to be solely attributed to varying levels of air circulation.

There were level × section interactions ($P \leq 0.02$) for percentage of heifers treated for BRD and percentage of heifers treated for BRD within the first 14 days (Table 5.1). Among heifers housed in the bottom deck, those in the nose were treated 39% more often ($P \leq 0.04$) compared to those in the BDM or BDR. There was no difference ($P \geq 0.17$) due to section in percentage of heifers treated for BRD among those housed in the upper deck. Of heifers in the nose sections, those in the BDN were treated for BRD 45% more often ($P = 0.03$) than those in the UDN. Among heifers housed in the bottom deck, those in the BDN were 32.4% more likely ($P = 0.05$) to be treated for BRD within the first 14 days than those in the BDR. Conversely, among heifers housed in the upper deck, those in the UDR were 53% more likely ($P = 0.05$) to be treated for BRD within the first 14 days than those in the UDN. Of heifers housed in the nose sections, those in the BDN were 33% more likely ($P = 0.05$) to be treated for BRD within the first 14 days than heifers in the UDN, and of heifers housed in the rear sections, those in the UDR were 53% more likely ($P = 0.04$) to be treated for BRD within the first 14 days than those in the BDR.

The BDN was the compartment where greatest temperatures were observed, and was also associated with the greatest frequency of treatment for BRD. Therefore, differences in temperature in this compartment may also be related to a greater risk for clinical illness. White et al. (2009) observed increased risk for BRD-related morbidity in calves housed in middle sections during transport, and speculated that increased commingling in these larger sections is the cause for this greater risk. Interestingly, percent morbidity of calves housed in middle sections was not different from other

compartments in the present experiment, but were numerically intermediate to the 2 smaller sections on both levels.

Initial BW did not differ ($P \geq 0.13$) by level or compartment (Table 5.2). Bodyweights measured at each 14-day interval for the following 56 days were also not different ($P \geq 0.0.21$) among levels or sections, when accounting for initial BW as a covariate. During the first 14 days, ADG showed a level × section interaction ($P = 0.02$). Gains of heifers in the nose sections were 0.85 kg/day greater ($P < 0.01$) in the bottom deck compared to the upper deck. Among heifers housed in the middle and rear sections, gains were not different ($P \geq 0.29$) between the 2 levels. In heifers housed in the bottom deck, those in the BDN tended ($P = 0.07$) to gain 0.58 kg/day more than those in the BDR. In heifers housed in the upper deck, those in the UDM gained 0.63 kg/day more ($P = 0.01$) compared to the UDN, whereas the UDR did not differ ($P \geq 0.12$) from the other 2 upper sections. It should be noted that the standard error for the mean ADG of heifers from the UDR was very large; therefore, this mean could not be separated as different from any other means. Gains from day 0 to 28 and from day 0 to 56 were not affected ($P \geq 0.46$) by level or section.

The differences observed for ADG from day 0 to 14 were unexpected. It was anticipated that sections resulting in increased ruminal temperature would in turn result in reduced ADG. However, heifers with the highest temperatures also exhibited greater gains. It is possible that calves in those compartments experienced more stress and greater shrink, providing these calves greater potential for compensatory gains upon arrival. It should be noted that this only occurred during the first 14 days, and that performance over the entire 56-day receiving period showed no relationship to area of the

truck during transit. Therefore, the results from the first 14 days likely have little biological significance. Camp et al. (1981) measured ADG of 11 loads of calves from day 0 to 29 and did not observe differences in those housed in upper and lower decks during transit. White et al. (2009) observed that ADG from arrival through revaccination decreased as placement within the truck moved from the nose to the rear, regardless of level. Similar trends were observed among heifers housed in the bottom deck in the present experiment, but of heifers housed in the upper deck, gains generally increased from the nose to the rear. Heifers housed in the UDR exhibited one of the numerically greatest mean ADG from day 0 to 14; however, a large standard error of this mean did not allow any statistically significant conclusions to be drawn from this compartment. The nose and rear sections of the truck are much smaller than the middle sections; therefore, fewer observations are available for these compartments. White et al. (2009) also noted this potentially confounding factor, and the conflicting results from that study and the present experiment may provide evidence of this unavoidable source of increased variation. Performance and morbidity data should be interpreted accordingly, keeping in mind that low numbers of observations decreases the power of the analyses.

To determine if ruminal temperature could be used to predict ADG, regression analyses were performed (Figures 5.2 to 5.4). One-third of the heifers were administered metaphylaxis on arrival; therefore, data for these heifers were not included in regression analyses as antimicrobials were not administered based on signs of illness. Temperature was not a reliable indicator of subsequent performance from day 0 to 14, from day 0 to 28, or from day 0 to 56 ($R^2 \leq 0.005$, $P \geq 0.25$). Regression analyses were also performed to determine if ruminal temperature during transit could be used to predict the day of first

and second antimicrobial treatments for BRD (Figures 5.5 and 5.6); however, temperature was not a reliable indicator of this morbidity measurement ($R^2 \leq 0.016$, $P \geq 0.12$).

IMPLICATIONS

The environmental conditions within the truck differ by compartment as indicated by differing mean ruminal temperatures. However, these temperatures do not appear to be a reliable indicator of subsequent calf morbidity and performance. Factors that may contribute to differences in morbidity and performance within loads include varying levels of stress (Grandin, 1997), behavior and activity (Knowles et al., 1997) among calves. Across loads, other sources of variation may include time of day (Cole et al., 1988), season (Knowles et al., 1997), distance traveled (Pinchak et al., 2004), and management methods prior to shipping (Step et al., 2008). Upon entry into the feedlot, cattle should be evaluated and managed according to risk level of the entire group, but particular attention to calves housed in the BDN compartment may be warranted.

LITERATURE CITED

Bryant, L. K., L. J. Perino, D. Griffin, A. R. Doster, and T. E. Wittum. 1999. A method for recording pulmonary lesions of beef calves at slaughter, and the association of lesions with average daily gain. Bov. Pract. 33:163-173.

Buhman, M. J., L. J. Perino, M. L. Galyean, T. E. Wittum, T. H. Montgomery, and R. S. Wingle. 2000. Association between changes in eating and drinking behaviors and respiratory tract disease in newly arrived calves at a feedlot. Am. J. Vet. Res. 61:1163-1168.

Camp, T. H., D. G. Stevens, R. A. Stermer, and J. P. Anthony. 1981. Transit factors affecting shrink, shipping fever and subsequent performance of feeder calves. J. Anim. Sci. 52:1219-1224.

Cole, N. A., T. H. Camp, L. D. Rowe, Jr., D. G. Stevens, and D. P. Hutcheson. 1988. Effect of transport on feeder calves. Am. J. Vet Res. 49:178-183.

Grandin, T. 1997. Assessment of stress during handling and transport. J. Anim. Sci. 75:249-257.

Griffin, D. 1997. Economic impact associated with respiratory disease in beef cattle. Vet. Clinics of N. Am. Food Anim. Pract. 13:367-377.

Knowles, T. G., P. D. Warriss, S. N. Brown, J. E. Edwards, P. E. Watkins, and A. J. Phillips. 1997. Effects on calves less than one month old of feeding or not feeding them during road transport of up to 24 hours. Vet. Rec. 140:116-124.

National Agricultural Statistics Service. 2006. Cattle death loss. Accessed March 27, 2010. http://usda.mannlib.cornell.edu/usda/current/CattDeath/CattDeath-05-05-2006.pdf

Pinchak, W. E., D. R. Tolleson, M. McCloy, L. J. Hunt, R. J. Gill, R. J. Ansley, and S. J. Bevers. 2004. Morbidity effects on productivity and profitability of stocker cattle grazing in the Southern Plains. J. Anim. Sci. 82:2773-2779.

Rose-Dye, T. K., L. O. Burciaga-Robles, C. R. Krehbiel, D. L. Step, R. W. Fulton, A. W. Confer, and C. J. Richards. 2011. Rumen temperature change monitored with remote rumen temperature boluses after challenges with bovine viral diarrhea virus and *Mannheimia haemolytica*. J. Anim. Sci. 89:1193-1200.

Sims, L. E., T. K. Dye-Rose, C. L. Goad, B. P. Holland, L. O. Burciaga-Robles, D. L. Step, C. R. Krehbiel, and C. J. Richards. 2009. Use of rumen temperature for health monitoring in cattle. Abstract presented at the National ASAS Meeting; Montreal, Quebec, Canada.

Step, D. L., C. R. Krehbiel, H. A. DePra, J. J. Cranston, R. W. Fulton, J. G. Kirkpatrick, D. R. Gill, M.E. Payton, M. A. Montelongo, and A. W. Confer. 2008. Effects of commingling beef calves from different sources and weaning protocols during a forty-two-day receiving period on performance and bovine respiratory disease. J. Anim. Sci. 86:3146-3158.

Wittum, T. E., N. E. Woollen, L. J. Perino, and E. T. Littledike. 1996. Relationships among treatment for respiratory tract disease, pulmonary lesions evident at slaughter, and rate of weight gain in feedlot cattle. J. Am. Vet. Med. Assoc. 209:814-818.

White, B. J., D. Blasi, L. C. Vogel and M. Epp. 2009. Associations of beef calf wellness and body weight gain with internal location in a truck during transportation. J. Anim. Sci. 87:4143-4150.

Table 5.1. Ruminal temperature and morbidity of feedlot heifers based on compartment of truck during transit

	Compartment of Truck									
	Bottom Deck			Upper Deck				*P*-Values[1]		
Item	Nose	Middle	Rear	Nose	Middle	Rear	SEM	L	S	L×S
n	20	113	24	16	117	7				
Ruminal temperature, °C	39.69^{c}	39.57^{bc}	39.59^{bc}	39.48^{b}	39.57^{bc}	39.30^{a}	0.06	<0.01	<0.01	<0.01
Treated for BRD, %	84.0^{b}	49.5^{a}	36.7^{a}	36.7^{a}	48.1^{a}	71.6^{ab}	21.1	0.63	0.43	0.03
Treated by day 14, %	52.1^{b}	40.0^{ab}	19.7^{a}	19.3^{a}	31.6^{ab}	72.5^{b}	26.9	0.71	0.73	0.02

[1]Comparisons: L = level (bottom deck vs. upper deck), S = section (nose vs. middle vs. rear), L×S = interaction between L and S.
[2]Day of treatment for bovine respiratory disease
[abc]Means within a row without a common superscript differ ($P \geq 0.05$).

Table 5.2. Performance of heifers based on compartment of truck during transit

	Compartment of Truck									
	Bottom Deck			Upper Deck				*P*-Values[1]		
Item	Nose	Middle	Rear	Nose	Middle	Rear	SEM	L	S	L×S
n	20	113	24	16	117	7				
BW, kg										
day 0	229.8	238.2	242.5	240.3	245.7	220.9	13.7	0.83	0.23	0.13
day 14[*]	266.8	263.1	258.3	254.1	263.6	257.5	19.8	0.63	0.77	0.89
day 28[*]	281.1	281.5	273.6	277.9	281.5	260.7	22.4	0.21	0.64	0.25
day 42[*]	301.2	303.9	301.3	300.2	305.0	314.8	23.4	0.53	0.96	0.96
day 56[*]	311.8	310.8	311.9	306.6	313.4	309.4	24.7	0.96	0.50	0.68
ADG, kg										
day 0 to 14	1.80[b]	1.57[b]	1.22[ab]	0.95[a]	1.58[b]	1.78[ab]	0.79	0.65	0.54	0.02
day 0 to 28	1.38	1.47	1.17	1.34	1.45	1.43	0.36	0.62	0.47	0.68
day 0 to 56	1.23	1.26	1.27	1.18	1.30	1.22	0.19	0.75	0.46	0.69

[1]Comparisons: L = level (bottom deck vs. upper deck), S = section (nose vs. middle vs. rear), L×S = interaction between L and S.
[ab]Means within a row without a common superscript differ ($P \geq 0.05$).
[*]BW on day 0 is a covariate.

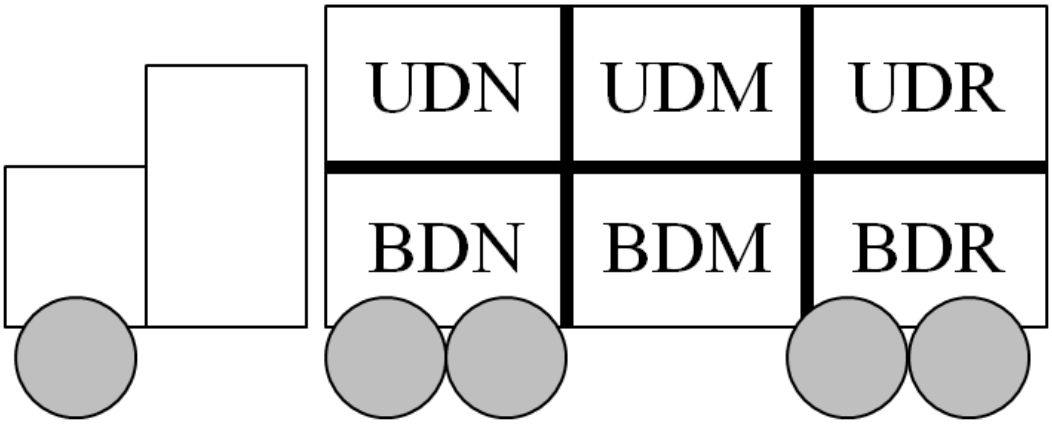

Figure 5.1. Depiction of truck areas. Abbreviations: UDN = upper deck nose, UDM = upper deck middle, UDR = upper deck rear, BDN = bottom deck nose, BDM = bottom deck middle, BDR = bottom deck rear.

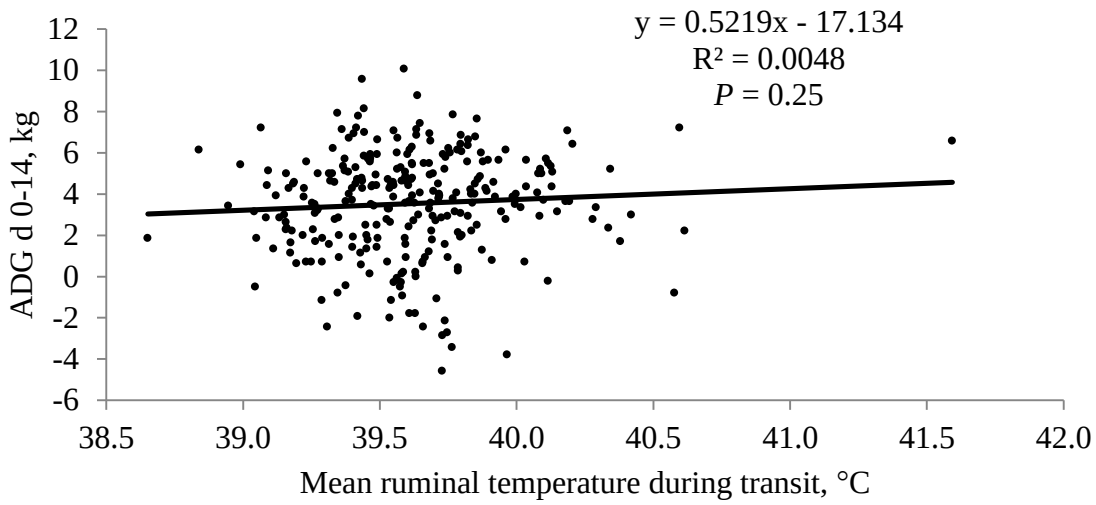

Figure 5.2. Regression of mean ruminal temperature during transit and average daily gain from d 0 to 14 (n = 279).

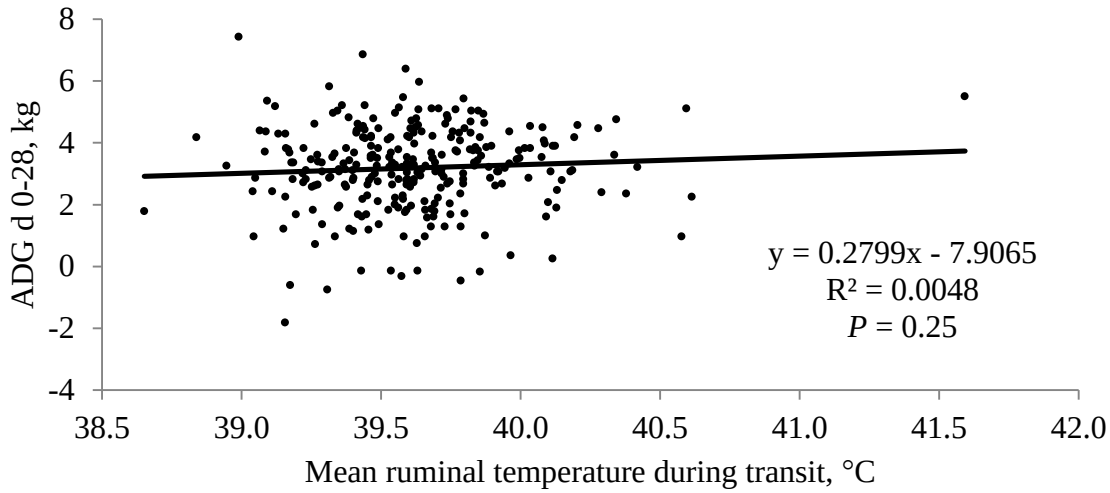

Figure 5.3. Regression of mean ruminal temperature during transit and average daily gain from d 0 to 28 (n = 276).

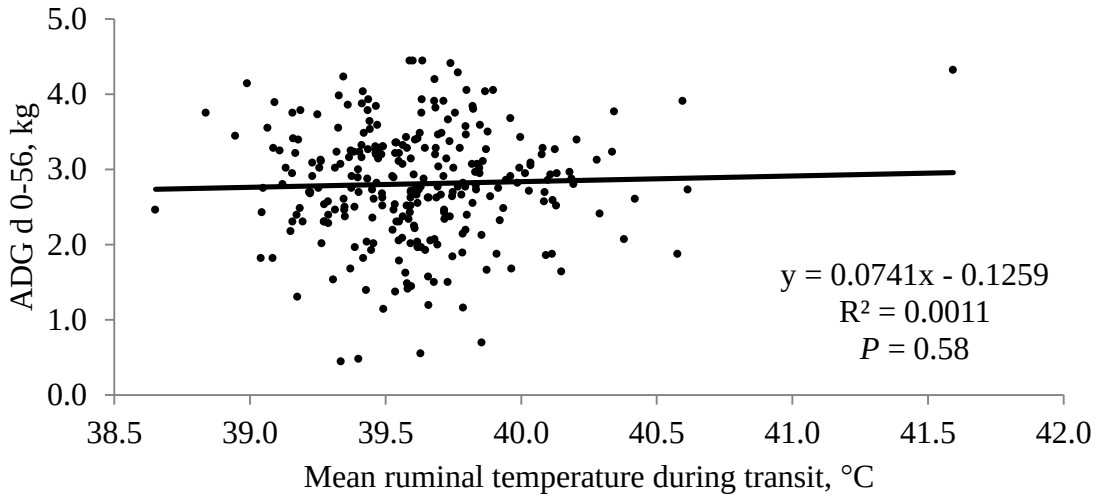

Figure 5.4. Regression of mean ruminal temperature during transit and average daily gain from d 0 to 56 (n = 274).

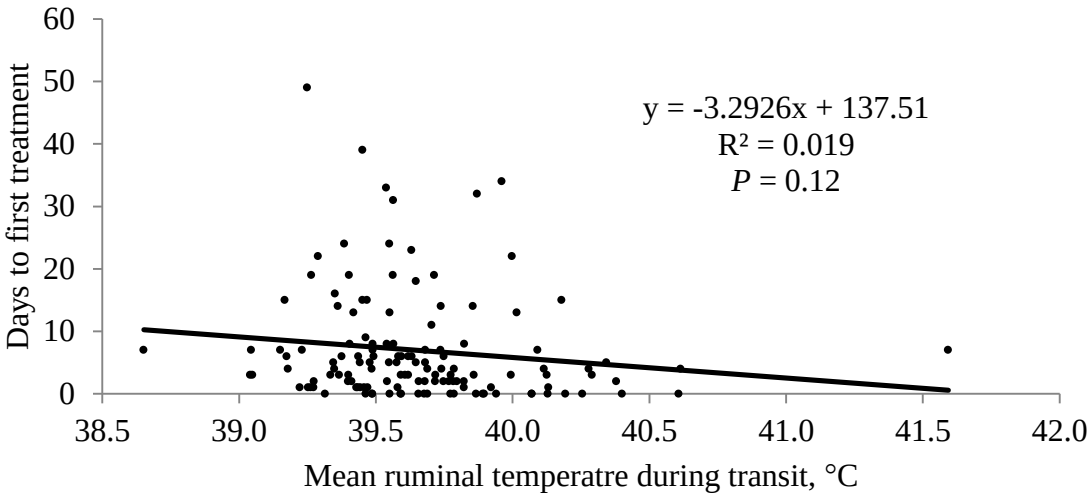

Figure 5.5. Regression of mean ruminal temperature during transit and days until first treatment for bovine respiratory disease (n = 132).

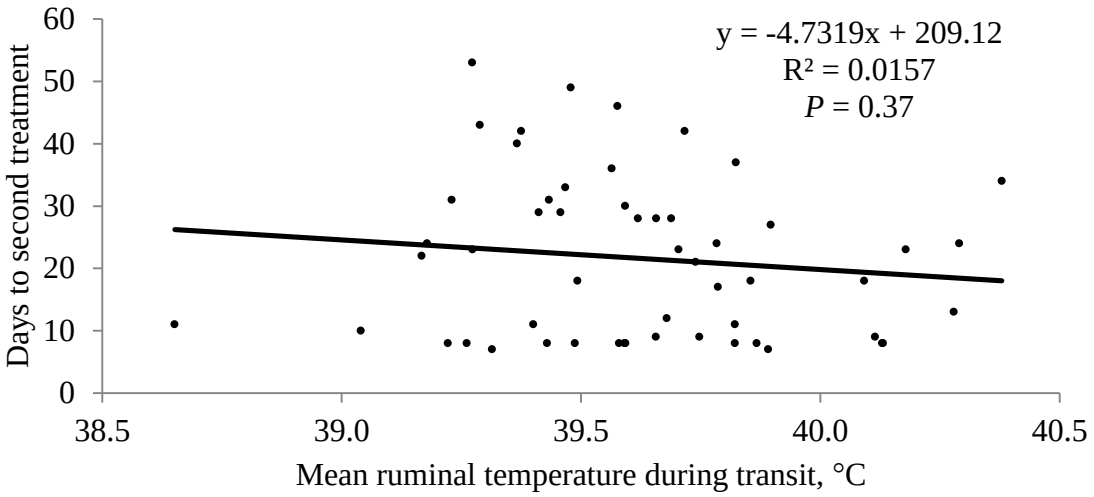

Figure 5.6. Regression of mean ruminal temperature during transit and days until second treatment for bovine respiratory disease (n = 54).

CHAPTER VI

RUMINAL ACIDOSIS CHALLENGE IMPACT ON RUMINAL TEMPERATURE IN FEEDLOT CATTLE

ABSTRACT

The objective of this experiment was to determine if ruminal temperature rise coincides with pH reduction using an acidosis challenge model. Twelve ruminally cannulated steers (518 ± 28 kg) were administered ruminal temperature monitoring devices which recorded temperature every 2 min. Steers were fed a 63% concentrate diet at 1.6% BW for 20 d before being randomly assigned to one of three acidosis challenge treatments: no dietary change (**CON**), half of daily DMI replaced with cracked corn (**HALF**), or all of daily DMI replaced with cracked corn (**CORN**). The challenge was initiated by ruminally dosing steers with their treatment diets. Ruminal pH and rectal temperatures (**RecT**) were recorded every 3 h for 72 h. All steers were offered CON diets at 24 and 48 h after challenge. Ruminal pH showed a treatment × d effect ($P = 0.01$). Ruminal pH of CORN steers was lower ($P = 0.03$) than HALF steers by 0.47 units on d 1, lower ($P \leq 0.004$) than HALF and CON steers by 0.68 units on d 2, and tended to be lower ($P \leq 0.10$) than HALF and CON steers by 0.34 units on d 3. Treatment did not affect ($P \geq 0.42$) RecT. Ruminal temperature (**RumT**) showed a treatment × d × h since feeding interaction ($P <$

0.01). At 3 h after challenge, RumT of CORN and HALF steers was 0.17°C higher ($P \leq$ 0.01) than CON steers. On d 2, RumT of CORN steers was 0.13°C higher ($P \leq 0.03$) than CON between 6 and 12 h after feeding. From 15 h to 21 h after feeding on d 2, RumT of HALF steers was 0.25°C higher ($P < 0.01$) than CORN and CON steers. On d 3, at the time of feeding until 3 h later, RumT of CORN steers was 0.15°C lower ($P \leq$ 0.04) than all other steers. Rectal temperature was correlated ($P \leq 0.01$) with RumT on all d for CON and CORN steers. Ruminal pH was negatively correlated ($P \leq 0.04$) with RecT on d 2 and RumT on d 1 in CORN steers, and RumT was negatively correlated ($P \leq$ 0.02) with ruminal pH in HALF and CON steers on d 1 and 3, respectively. The amount of time above RumT of 39.0 or 39.45°C was correlated ($P \leq 0.05$) with time spent below a ruminal pH of 5.5 in CORN steers; however, time above RumT of 39.0°C did not differ ($P = 0.87$) among treatments. Results indicate that RumT monitoring has potential to detect changes in ruminal temperature that correspond with declining ruminal pH; however, this relationship may only be evident during an acidotic episode.

KEY WORDS: acidosis, body temperature, cattle

INTRODUCTION

Metabolic diseases are the second leading cause of mortality in feedlot cattle, with ruminal acidosis accounting for most digestive disturbances (Nagaraja and Lechtenberg, 2007). Signs of ruminal acidosis include diarrhea, dehydration, absence of digestive motility, anorexia, and incoordination. Cattle that survive a bout of acidosis may exhibit long-term decreased feed efficiency as the result of a damaged ruminal epithelium, and are more susceptible to additional bouts of acidosis.

Subclinical ruminal acidosis is characterized as a ruminal pH between 5.0 and 5.5 (Nagaraja and Titgemeyer, 2007). Cattle suffering from subclinical acidosis typically do not exhibit outward signs of the disease. Lactic acid concentrations are normal (0-5 mmol), and VFA concentrations are high (150-225 mmol). *Streptococcus bovis* populations are unchanged, while *Lactobacillus* species populations are increased, resulting in an increase in populations of lactic acid producing bacteria. However, populations of lactic acid-utilizing bacteria, such as *Megasphaera elsdenii* are also increased, resulting in no lactic acid accumulation. (Nagaraja and Lechtenberg, 2007)

Clinical acidosis is characterized by a ruminal pH of less than 5.0. Cattle suffering from clinical acidosis will exhibit outward signs of the disease. Signs include reduced feed intake, or anorexia, and lethargy. Cattle may appear to be uncoordinated and generally uncomfortable. Frequency of ruminal contractions will be highly reduced, or cease completely. Feces of cattle experiencing clinical acidosis will initially be soupy, then becoming watery or foamy. Cattle may lie down, and be unwilling to rise, and tuck their heads as is observed in cases of parturient paresis. (Nagaraja and Lechtenberg, 2007)

Lactic acid concentrations are high (50-120 mmol) in cattle suffering from clinical acidosis. Concentrations of other VFAs in the rumen are high initially, but then fall below normal (less than 100 mmol) as many microorganisms cannot survive the low pH environment. *Streptococcus bovis* populations increase initially, but then decline as pH falls below 6.0. *Lactobacillus* species are increased, resulting in an increase in lactic acid-producing bacteria. However, unlike subclinical acidosis, lactic acid utilizers are decreased, resulting in a heavy accumulation of lactic acid. Endotoxins are present in the

rumen, along with other toxic products, such as ethanol and amines. (Nagaraja and Lechtenberg, 2007)

Diets that contain large amounts of rapidly fermentable starch are responsible for causing ruminal acidosis in cattle when these animals are not adapted to such a diet. With the increased starch consumption, *Streptococcus bovis* will increase in population. Lactic acid is a major product of digestion for these bacteria, causing accumulation of lactic acid in the rumen, resulting in a sharp decrease in pH (less than 5.0). Many other bacteria are not able to survive this low-pH environment and will wash out. This leads to less competition among bacteria for substrates, allowing the lactic acid-producing bacteria to thrive. *Streptococcus bovis* is responsible for the initial lactic acid accumulation, but they are not able to reproduce at a rapid rate in an extremely acidic environment (Finlayson, 1986). At this point, *Lactobacillus* species will increase in population, as these bacteria are able to tolerate a low pH environment (Finlayson, 1986). The major substrate utilized by *Lactobacillus* species is glucose, which is produced by *Streptococcus bovis* in the breakdown of starch. Like *S. bovis*, *Lactobacillus* species also produce lactic acid as a major endproduct, further adding to the lactic acid accumulation and pH decline. The animal is unable to utilize this lactic acid, and is also unable to clear lactic acid from the body at the rate at which it is produced. Therefore, blood concentrations of this acid will increase, reducing blood pH (Owens et al., 1998).

The first line of defense in preventing ruminal acidosis is proper nutritional management. Allowing cattle to adapt to a high-grain diet is essential in preventing an accumulation of lactic acid. In any high-grain diet, lactic acid will be produced as a product of starch digestion. Most of the bacteria that utilize starch produce lactic acid as

a major end product of digestion. There are many bacteria that produce lactic acid, and very few that utilize it. Few bacteria are more important than *Megasphaera elsdenii* in preventing lactic acidosis, as this species ferments an estimated 60-80% of ruminal lactic acid (Counotte et al., 1981). However, this bacterial species must be allowed to grow in population gradually. If cattle are abruptly shifted from a high-forage to a high-grain diet, these bacteria will not be able to keep up with the rate of lactic acid production. This will cause an accumulation of lactic acid, and consequently, a decline in pH. *Megasphaera elsdenii* are tolerant of a low ruminal pH; however, growth rates are diminished as pH falls below 5.5 (Therion et al., 1982). A slow adaptation to a high-grain diet will allow *Megasphaera elsdenii* to grow in population at the same rate as lactic acid production, thereby decreasing lactic acid accumulation and incidence of lactic acidosis.

In addition to regulating the quantity of start that is introduced during grain adaptation, nutritionists must also consider the rate at which that starch is fermented in the rumen. Starch from processed grains will be more readily available compared to non-processed grains, and starch from dry-processed grains (rolling) will be more readily available compared to wet processing methods (steam flaking; Stock, 2007). A combination of rapidly- and slowly-fermentable starch sources will enhance cattle performance and reduce the risk of ruminal acidosis (Stock, 2007).

The detrimental effects of ruminal acidosis are far-reaching. Both treatment and prevention may be complicated if diets are not properly managed. As cattle experiencing subacute ruminal acidosis may not exhibit external signs of the disease (Nagaraja and Titgemeyer, 2007), diagnosis is difficult in some animals. Therefore, development of

new methods of identifying subacute ruminal acidosis may benefit the feedlot industry by allowing feedlot managers to more quickly intervene before ruminal pH falls to an acute acidotic level, or alter management to reduce the occurrence of acidosis.

Heat of glucose fermentation in ruminal fluid is negatively correlated with ruminal pH (Arieli et al., 1988); therefore, the temperature of the rumen may provide valuable information in identification of acidotic episodes in cattle. Ruminal temperature monitoring has been shown to be a reliable measure of body temperature in dairy cows (Bewley et al., 2008) and beef steers (Rose-Dye et al., 2011). AlZahal et al. (2008) continuously monitored ruminal pH and temperature in dairy cows, and determined that low ruminal pH is associated with an increased ruminal temperature. The objective of this experiment was to determine if ruminal temperature monitoring could accurately detect ruminal temperature rises associated with a reduction in ruminal pH in beef steers subjected to an acidosis challenge.

MATERIALS AND METHODS

Animals

All procedures were approved by the Oklahoma State University Animal Care and Use Committee. Twelve ruminally cannulated Angus crossbred steers (BW = 518 ± 28 kg) were utilized in a completely randomized design experiment. One steer exhibited greater than normal body temperatures throughout the experiment and was therefore removed from the dataset. Mean ruminal temperatures of this steer were more than 4 standard deviations greater than other steers within the same treatment group, and were more than 3 standard deviations greater than all other steers. Steers were fed a 63%

concentrate diet that contained 22 mg/kg of monensin (Table 6.1) for 20 d prior to the acidosis challenge. The diet was offered at 1.6% of BW (DM basis). Steers were housed indoors in 2.4 × 3.8 m individual stalls without environmental control. Water was available ad libitum via automatic water units located in each stall.

Experiment

Steers were randomly assigned to one of three acidosis challenge treatments: No dietary change (**CON**, n = 4), half of daily DMI replaced with cracked corn (**HALF**, n = 3), or all of daily DMI replaced with cracked corn (**CORN**, n = 4). Treatment diets were dosed through the rumen cannula at the initiation of the experiment. Rectal temperatures (**RecT**) were measured (GLA M-500, GLA Electronics, San Luis Obispo, CA), and ruminal fluid was obtained for measurement of pH (Model SP70P, VWR International, West Chester, PA) at 3-h intervals for 72 h beginning immediately prior to dosage of treatment diets. Ruminal fluid was obtained via suction aspiration by inserting Tygon tubing equipped with a strainer (Raun and Burroughs, 1962) through slit cuts in the cannula caps to prevent ruminal contents from escaping during sampling. All steers were offered the base diet at 1.6% of BW 24 and 48 h after challenge. All steers consumed the entire amount of feed offered with the exception of one steer belonging to the CORN treatment, which refused 89.8% of the feed offered at 24 h and 61.9% of the feed offered at 48 h after challenge.

One week prior to initiation of the experiment, steers were administered a ruminal temperature monitoring bolus (Strategic Solutions International, LLC; Stillwater, OK) through the rumen cannula, which remained in the reticulum throughout the duration of

the experiment. Boluses were programmed to store current ruminal temperatures (**RumT**) every 2 min. At the end of the experiment, boluses were retrieved and stored data were downloaded to a spreadsheet program.

Individual steer temperatures associated with water drinking events were identified and removed from the data set. The beginning of a drinking event was identified by a RumT decrease of at least 0.28°C from the previous measurement. The end of the water drinking event was identified when RumT either ceased to increase over a 10 min time span, or increased to the last temperature observed prior to the drinking event.

Statistical Analysis

For all statistical analyses, steer was the experimental unit and the random effect was steer within treatment. Response variables included pH, RecT, RumT, amount of time spent at a ruminal pH below 5.5 and 5.0, and amount of time spent at a RumT greater than 39.0°C and 39.45°C. For ruminal pH measures, the change from a given sampling time to the next was assumed to be linear, and the estimated point in time when pH reached 5.5 and 5.0 thresholds was calculated. The total estimated amount of time spent below these pH thresholds, and the amount of time above RumT thresholds was summarized by d prior to analyses.

To determine the effects of challenge treatment, day, sampling time, and all interactions on ruminal pH and RecT measurements, data were analyzed using the MIXED procedure of SAS (SAS Institute, Inc., Cary, NC), with sampling time serving as a repeated measure in an autoregressive structure. Ruminal temperatures were averaged

in 15 min intervals and analyzed using the GLIMMIX procedure of SAS with each 15 min interval serving as a repeated measure in a banded Toeplitz structure. The covariance structure in both analyses was selected by subjecting the model to multiple covariance structures, and the best fit model was selected to contain the covariance structure that yielded the smaller Akaike's and Schwarz's Bayesian criteria. Amount of time spent below ruminal pH thresholds of 5.0 and 5.5 and amount of time spent above RumT thresholds of 39.0 and 39.45°C were summarized by day; therefore, treatment, d, and the associated interaction were used as fixed effects in these MIXED models.

Least squares means were calculated and considered significant when $P \leq 0.10$. All pairwise comparisons were made using Tukey's adjustment methods. Mean differences are discussed when $P \leq 0.05$ and considered tendencies when $0.05 < P \leq 0.10$.

The CORR procedure of SAS was used to determine Pearson correlations between response variables of ruminal pH, RecT, and RumT. In these analyses, RecT and ruminal pH measurements were paired with the single RumT measured at the time closest to the time of RecT measurement. Data were analyzed for all treatment and d combinations. Pearson correlations were also determined for the amount of time spent above RumT of 39.0 and 39.45 compared to the amount of time spent below ruminal pH of 5.5 and 5.0 within each treatment.

RESULTS AND DISCUSSION

Ruminal pH measures during the experiment are presented in Figure 6.1. The interaction of treatment × d × h was not significant ($P = 0.59$). Ruminal pH showed a treatment × d interaction ($P = 0.02$). Ruminal pH did not differ ($P \geq 0.62$) between

HALF and CON steers on any d of the experiment. On d 1, replacing the entire daily diet with cracked corn for the CORN steers decreased ($P = 0.05$) ruminal pH by 0.47 units compared to steers dosed with the HALF diet, and tended ($P = 0.08$) to decrease ruminal pH by 0.40 units compared to CON. Compared to CON and HALF steers, ruminal pH of CORN steers was 0.67 units lower ($P < 0.01$) on d 2. Ruminal pH of CORN steers did not differ ($P \geq 0.11$) from HALF and CON steers on d 3. There was no treatment × h interaction ($P = 0.47$) for ruminal pH; however, there was a d × h interaction ($P < 0.01$) for ruminal pH. At h 0 and 3 after feeding, ruminal pH was 0.72 and 0.67 units lower ($P \leq 0.05$), respectively, on d 2 and 3 compared to d 1. This indicates that d 1 dosing reduced pH such that values observed on d 2 and 3 had not yet recovered to pre-dosing levels. At 6 h after feeding, ruminal pH was 0.21 units lower ($P \leq 0.02$) on d 1 and 2 compared to d 3. At 9 h after feeding, ruminal pH was 0.20 units lower ($P = 0.05$) on d 2 compared to d 3, and at 18 h after feeding, ruminal pH was 0.24 units lower ($P = 0.05$) on d 1 compared to d 3. The 6 to 18 h responses collectively indicate that the magnitude of pH change was more pronounced during the first 2 d after challenge compared to d 3.

Ruminal pH of CORN steers was 0.36 units lower ($P \leq 0.002$) on d 2 compared to d 1 and 3, which were not different ($P = 0.96$). Replacing half of the daily DMI with cracked corn tended ($P = 0.07$) to decrease ruminal pH by 0.19 units on d 1 compared to d 2, but ruminal pH on d 3 was not different ($P \geq 0.36$) than either d 1 or d 2. Ruminal pH of CON steers did not differ ($P \geq 0.46$) by d of the experiment.

Results of time spent below ruminal pH of 5.5 and 5.0 and time spent above temperatures of 39.0 and 39.45°C are shown in Table 6.2. There was a treatment × d interaction ($P < 0.001$) for time spent below a ruminal pH of 5.5. No differences ($P \geq$

0.86) were observed between HALF and CON steers with respect to time spent below a ruminal pH of 5.5. No treatment differences ($P \geq 0.16$) were observed on d 1. On d 2, ruminal pH of CORN steers was less than 5.5 for 892 min longer ($P \leq 0.002$) than HALF and CON steers. On d 3 of the experiment, ruminal pH of steers administered the CORN treatment tended ($P \leq 0.08$) to be less than 5.5 for 414 min longer than HALF and CON steers.

No differences ($P \geq 0.85$) were observed among d within HALF and CON steers for time spent below ruminal pH of 5.5. Within steers administered the CORN treatment, ruminal pH on d 2 was less than 5.5 for 529 min longer ($P < 0.001$) than on d 1 and 3 which were not different ($P = 0.43$). Although no pH measurements below 5.0 were observed in CON and HALF steers, due to large standard errors observed in CORN steers, there were no differences ($P \geq 0.24$) in time below pH of 5.0 among treatments or d.

Ruminal pH exhibits daily fluctuations in cattle and at times may fall below 5.5 even in animals considered to be at low risk for experiencing ruminal acidosis (Dohme et al., 2008), if only for a short time. Therefore, ruminal acidosis in this study was considered to have occurred when pH was below thresholds of 5.5 (subacute) and 5.0 (acute) for at least three consecutive sampling times which results in a minimum of 6 h. Acute acidosis was successfully induced in 2 of the 4 steers dosed with the CORN treatment, whereas subacute acidosis was successfully induced in 1 of the CORN steers. The CORN steer that did not experience either level of acidosis spent a maximum of 5.7 h/d below a pH of 5.5.

Ruminal pH is highly variable, both across individual animals and within an individual. It is not uncommon for animals consuming the same diet to exhibit ruminal pH levels that range in values by 1 or more pH units (Schwartzkopf-Genswein et al., 2003). Additionally, continuous monitoring in dairy cows and feedlot steers has shown that ruminal pH may fluctuate by as much as 1.5 units/d (Beauchemin, 2007). No level of ruminal acidosis was observed in steers administered CON or HALF treatments in the present experiment. The mean range of ruminal pH values observed in CORN steers over the course of the experiment was 1.54 units, which is comparable to those observed by others after an acidosis challenge (Dohme et al, 2008; Erickson et al., 2003), whereas mean range of ruminal pH values in all other steers was only 1.29 units.

Rectal temperature was not affected ($P \geq 0.22$) by treatment; however, there was a d × h since feeding interaction ($P = 0.001$, Figure 6.2). At challenge and feeding, RecT was 0.24°C higher ($P \leq 0.007$) for d 1 compared to d 2 and 3. This is likely the result of bringing steers through the handling facility where treatment diets were dosed, reflecting an increased level of exercise, stress, or both at the initiation of the challenge. For d 3, RecT was 0.15°C greater ($P = 0.03$) compared to d 2 at 9 h after feeding. Also on d 3, RecT was 0.16°C higher ($P \leq 0.04$) at 9 and 21 h after feeding, and tended ($P = 0.10$) to be 0.12°C higher at 12 h after feeding compared to d 1. Rectal temperature also tended ($P = 0.06$) to be 0.14°C higher at 12 h after feeding for d 2 compared to d 1. Generally, the highest RecT occurred at 9 h after feeding (1700), and lowest RecT occurred at 21 h after feeding (0500). The daily fluctuations in RecT were representative of normal diurnal patterns in mature cattle (Wrenn et al., 1961). Throughout the experiment, mean ambient temperature inside the barn was 15.86°C. Furthermore, maximum ambient

temperature on d 1, 2, and 3 was 18.93, 18.65, and 18.81°C, respectively. Therefore, greater RecT on d 3 cannot be explained by environmental conditions. It is possible that greater temperatures on this d reflect an increased level of stress as the result of repeated samplings over the course of 72 h.

Averaged RumT were not different (mean = 38.90 ± 0.07°C, $P = 0.26$) among treatments during the week prior to challenge (data not shown). After challenge, RumT showed a treatment × d × hours since feeding interaction ($P < 0.001$, Figure 6.3). There were no treatment differences ($P \geq 0.20$) at the time of challenge. At 3 h after challenge, RumT of CORN and HALF steers was 0.17°C higher ($P \leq 0.01$) than that of CON, and RumT of HALF steers remained 0.15°C higher ($P = 0.01$) than CON at 6 h after challenge. At 9 and 12 h after challenge, RumT was not different ($P \geq 0.11$) among treatments. Ruminal temperatures of HALF steers were higher ($P \leq 0.03$) than CON by a mean of 0.18°C between 15 and 21 h after challenge, and was 0.19°C higher ($P \leq 0.001$) than CORN at 18 and 21 h after challenge.

On d 2, RumT of HALF steers was greater ($P \leq 0.02$) than CON at 3, 6, 12, 15, 18, and 21 h after feeding by 0.17, 0.17, 0.22, 0.26, 0.24, and 0.25°C, respectively (Figure 6.3). Also on d 2, RumT of CORN steers was greater ($P \leq 0.03$) than CON at 6, 9, and 12 h after feeding by 0.14, 0.13, and 0.11°C, respectively. Ruminal temperature of CORN steers reached its highest point at 6 h after feeding, but RumT of HALF steers continued to rise until 15 h after feeding. This resulted in a greater ($P \leq 0.001$) RumT in HALF steers compared to CORN between 15 and 21 h after feeding by a mean of 0.24°C.

On d 3, RumT of CORN steers was lower ($P \leq 0.04$) than the mean RumT of HALF and CON by 0.15°C and 0.21°C at 0 and 3 h after feeding, respectively. At 6, 9, and 21 h after feeding, RumT of steers administered the HALF diet was 0.17, 0.13, and 0.11°C higher ($P \leq 0.04$), respectively, than CON. Ruminal temperature of CORN steers was lower ($P \leq 0.03$) than HALF by 0.16, 0.12, and 0.11°C at 6, 9, and 15 h after feeding, respectively. Ruminal temperature was not different ($P = 0.36$) among treatments at the completion of the experiment.

The greatest response in RumT occurred during the hours after feeding coinciding with ruminal fermentation of feed. The diurnal pattern of observed RumT was typical of that reported by others (Bewley et al., 2008; Dye-Rose et al., 2009). Ruminal temperatures were generally greater for steers administered the HALF diet compared to CON, and RumT of CORN steers were also greater than CON at various points throughout the experiment. Steers assigned to the HALF diet consistently had greater RumT, even after removal of an outlier steer, but it is not clear why this occurred. Replacing half of the daily DMI with corn did not result in acidosis in this experiment; therefore, differences in RumT among these steers cannot be attributed to incidence of low ruminal pH.

AlZahal et al. (2008) induced subacute ruminal acidosis in dairy cows, and continuously monitored ruminal temperature and pH using a common electrode. The acidosis challenge caused 0.33 and 0.42 unit reductions in mean and minimum ruminal pH, respectively. Results indicated that mean ruminal temperature of acidotic cows was 39.21°C, which was 0.67°C greater than mean ruminal temperature of control cows. Also, acidotic cows spent a greater amount of time above temperature thresholds of 39.0

and 39.2°C. These measures were not affected by treatment in the present experiment, where overall mean RumT were not different between CON and CORN steers (mean = 39.93°C), and time spent above RumT of 39.0 and 39.45°C were not affected by treatment. These results are contrary to those reported by AlZahal et al. (2008), in which a change in diet fed occurred and the experimental period lasted one week, compared to 3 d in the present study.

Correlations between response variables of ruminal pH, RecT, and RumT for all treatment and d combinations are shown in Table 6.3. Rectal temperatures were correlated ($P \leq 0.01$) with RumT in all treatment groups on all d, with the exception of HALF steers on d 1 and 2. The unexpectedly high RecT along with the reduced sample size in the HALF treatment group may have contributed to lack of correlations as RecT and RumT were correlated (r = 0.54, $P = 0.007$) in these steers on d 3. Significant correlation coefficients ranged from 0.43 to 0.70.

On d 2, ruminal pH of HALF steers was correlated (r = -0.44, $P = 0.03$) with RecT. No other correlations were observed ($P \geq 0.16$) between ruminal pH and RecT in CON or HALF steers during the experiment; however, it may be noted that numerically in these treatment groups, the d with the lowest pH had the highest RecT. Also, all r values were negative with the exception of CON steers on d 1. In steers assigned to the CORN treatment, ruminal pH was correlated (r = -0.36, $P = 0.04$) with RecT on d 2, and tended ($P = 0.06$) to be correlated (r = -0.34) with RecT on d 3.

In CON steers, ruminal pH was correlated (r = -0.46, $P = 0.01$) with RumT on d 3, but not on d 1 or 2 ($P \geq 0.33$). In steers administered the HALF diet, ruminal pH was strongly correlated (r = -0.64, $P = 0.001$) with RumT on d 1, but not on d 2 or 3 ($P \geq$

0.70). Ruminal pH exhibited a strong correlation (r = -0.63, $P < 0.001$) with RumT in CORN steers on d 1, and tended ($P = 0.06$) to be correlated (r = -0.33) with RumT on d 2, but no correlations were detected on d 3 ($P = 0.54$). Interestingly, d 1 and 2 had the lowest ruminal pH measurements observed in CORN steers, and were also the d that showed relationships between pH and RumT.

Bewley et al. (2008) utilized intra-ruminal temperature monitoring boluses in dairy cows, and observed a correlation coefficient of 0.645 between rectal and ruminal temperatures based on 2,042 data pairs. Correlation coefficients between RumT and RecT of CON steers ranged from 0.43 (d 3) to 0.68 (d 2). Correlations between RumT and RecT of CORN steers which ranged from 0.63 (d 3) to 0.70 (d 2) were stronger than those observed in the CON and HALF treatments. With the exception of CON steers on d 3, correlations between RumT and RecT in these steers were comparable to those observed by Bewley et al. (2008), indicating that RumT was a reliable measure of body temperature in this study. Temperatures in the reticulo-rumen exhibit greater variation than temperatures measured in the rectum, as the environment within the reticulo-rumen is exposed to temperature-altering factors including introduction of feed and water. However, both methods of temperature measurements have been established as reliable indicators of temperature status (Bhattacharya and Warner, 1968; Beatty et al., 2008).

Correlations between critical point time response measures of time spent above RumT and below ruminal pH thresholds are shown in Table 6.4. Ruminal pH did not fall below 5.0 in steers assigned to either the CON or HALF treatments; therefore, correlations between time below pH of 5.0 with RumT above 39.0 and 39.45°C are only available for steers assigned to the CORN treatment. For CON and HALF steers, time

spent below a pH of 5.5 was not correlated ($P \geq 0.24$) with time spent above RumT of 39.0 or 39.45°C. Positive correlations were observed for time that ruminal pH was less than 5.5 with time that RumT was greater than 39.0°C (r = 0.57, $P = 0.05$) and with time that RumT was greater than 39.45°C (r = 0.66, $P = 0.02$) in CORN steers. Time spent below a pH of 5.0 tended (r = 0.50, $P = 0.10$) to be correlated with time that RumT was greater than 39.45°C in CORN steers.

AlZahal et al. (2008) reported an r of 0.45 between time below ruminal pH of 5.6 and time above ruminal temperature of 39.4°C in dairy cows experiencing acidosis. Steers on the CORN treatment exhibited even stronger correlations between time below ruminal pH of 5.5 and time that RumT was greater than 39.0 and 39.45°C in the present experiment. These indicate that extended periods of time spent above these RumT thresholds could be caused by periods of sustained low ruminal pH. However, steers from all challenge treatment groups exhibited sustained periods of RumT greater than 39.0°C. Positive correlations were observed for CORN steers between time above RumT of 39.0°C and time below pH of 5.5; however, it should be noted that time above RumT of 39.0°C was not different among the three challenge treatments. Consequently, measurements of time spent above RumT of 39.0°C are likely not sufficient to determine changes occurring in ruminal pH. Some RumT measurements above 39.45°C were observed in HALF steers, yet only CORN steers exhibited ruminal pH measurements below 5.0. Therefore, improved benchmark measurements for feedlot cattle must be determined to effectively utilize temperature monitoring for ruminal acidosis detection.

In summary, ruminal temperature monitoring is a viable means of monitoring body temperature that is highly correlated to commonly measured rectal temperatures.

Ruminal pH and time below specific pH benchmarks are common indicators of acidosis. Only the CORN treatment had significant pH declines on d 1 and d 2, and these resulted in significant, moderate to strong negative correlations with rectal and ruminal temperature increases. Body temperatures in normal animals are affected by many factors such as individual animal differences, time of day and activity level. They can also be affected by heat of fermentation, ambient temperatures, and inclement health including acidosis. These variations suggest that using temperature to detect inclement health may benefit from comparison of an individual animal's temperatures to those of others in their management group as well as individual animal history. This should improve detection of animals requiring further evaluation, and upon consideration of other factors such as viral or bacterial infection, the potential of acidosis should be considered. More aggressive challenge studies and evaluation of production animals diagnosed with acidosis may give more dynamic relationships of ruminal temperature and acidosis that could result in patterns that differentiate from viral and bacterial infections.

LITERATURE CITED

AlZahal, O., E. Kebreab, J. France, M. Froetschel, and B. W. McBride. 2008. Ruminal temperature may aid in the detection of subacute ruminal acidosis. J. Dairy Sci. 91:202-207.

Arieli, A., Y. Aharoni, S. Zamwel, and H. Tagari. 1988. Effect of ratio of roughage concentrate on glucose-induced heat production in sheep rumen fluid in vitro. J. Dairy Sci. 71:964-970.

Beatty, D. T., A. Barnes, E. Taylor, and S. K. Maloney. 2008. Do changes in feed intake or ambient temperature cause changes in cattle rumen temperature relative to core temperature. J. Therm. Biol. 33:12-19.

Beauchemin, K. A. 2007. Ruminal acidosis in dairy cows: Balancing physically effective fiber with starch availability. Pages 16-27 in Proc. of the 18th Annual Florida Ruminant Nutrition Symposium. Univ. of Florida, Gainesville.

Bewley, J. M., M. E. Einstein, M. W. Grott, and M. M. Schutz. 2008. Comparison of reticular and rectal core body temperatures in lactating dairy cows. J. Dairy Sci. 91:4661-4672.

Bhattacharya, A. N., and R. G. Warner. 1968. Influence of varying rumen temperature on central cooling or warming and on regulation of voluntary feed intake in dairy cattle. J. Dairy Sci. 51:1481-1489.

Counotte, G. H. M., R. A. Prins, R. H. A. M. Janssen, and J. A. Debie. 1981. Role of *Megasphaera elsdenii* in the fermentation of DL-[2-^{13}C]lactate in the rumen of dairy cattle. Appl. Environ. Microbiol. 42:649-655.

Dohme, F., T. J. DeVries, and K. A. Beauchemin. 2008. Repeated ruminal acidosis challenges in lactating dairy cows at high and low risk for developing acidosis: Ruminal pH. J. Dairy Sci. 91:3554-3567.

Dye-Rose, T. K., L. O. Burciaga-Robles, C. R. Krehbiel, and C. J. Richards. 2009. Effect of diet on rumen temperature during grain adaptation and finishing in individually fed calves. Oklahoma State University Animal Science Research Report. http://www.ansi.okstate.edu/research/research-reports-1/2009/012%20Trista%20Dye%20Final.pdf. Accessed 5 April 2011.

Erickson, G. E., C. T. Milton, K. C. Fanning, R. J. Cooper, R. S. Swingle, J. C. Parrott, G. Vogel, and T. J. Klopfenstein. 2003. Interaction between bunk management and monensin concentration on finishing performance, feeding behavior, and ruminal metabolism during an acidosis challenge with feedlot cattle. J. Anim. Sci. 81:2869-2879.

Finlayson, H. J. 1986. The effect of pH on the growth and metabolism of *Streptococcus bovis* in continuous culture. J. Appl. Bacteriol. 61:201-208.

Nagaraja, T. G., and K. F. Lechtenberg. 2007. Acidosis in feedlot cattle. Vet. Clin. Food Anim. 23:333-350.

Nagaraja, T. G., and E. C. Titgemeyer. 2007. Ruminal acidosis in beef cattle: The current microbiological and nutritional outlook. J. Dairy Sci. 90(Suppl.):E17-E38.

Owens, F. N., D. S. Secrist, W. J. Hill, and D. R. Gill. 1998. Acidosis in cattle: A review. J. Anim. Sci. 76:275-286.

Raun, N. S. and W. Burroughs. 1962. Suction strainer technique in obtaining rumen fluid samples from intact lambs. J. Anim. Sci. 21:454-457.

Rose-Dye, T. K., L. O. Burciaga-Robles, C. R. Krehbiel, D. L. Step, R. W. Fulton, A. W. Confer, and C. J. Richards. 2011. Rumen temperature change monitored with remote reporting rumen temperature boluses following challenges with Bovine Viral Diarrhea Virus and *Mannheimia haemolytica*. J. Anim. Sci. 89:1193-1200.

Schwartzkopf-Genswein, K. S., K. A. Beauchemin, D. J. Gibb, D. H. Crews, Jr., D. D. Hickman, M. Streeter, and T. A. McAllister. 2003. Effect of bunk management on feeding behavior, ruminal acidosis and performance of feedlot cattle: A review. J. Anim. Sci. 81:E149-158.

Stock, R. 2007. Associative effects and management – Combinations of processed grains. Pages 166-172 in Proc. of the Cattle Grain Processing Symposium. Oklahoma State Univ., Stillwater.

Therion, J. J., A. Kistner, and J. H. Kornelius. 1982. Effect of pH on growth rates of rumen amylolytic and lactilytic bacteria. Appl. Environ. Microbiol. 44:428-434.

Wrenn, T. R., J. Bitman, and J. F. Sykes. 1961. Diurnal patterns of bovine body temperature. J. Dairy Sci. 44:2077-2080.

Table 6.1. Ingredients and nutrient composition of base diet

Ingredient, %	
Dry-rolled corn	35.5
Dried distillers grains	18.0
Ground prairie hay	19.0
Ground alfalfa hay	18.0
Liquid Supplement[1]	3.5
Dry Supplement[2]	6.0
Nutrient composition[3]	
DM, %	84.66
NE_m, Mcal/kg	1.80
NE_g, Mcal/kg	1.07
CP, %	15.01
ADF, %	19.59
NDF, %	30.29
Calcium, %	0.61
Phosphorus, %	0.29

[1]Synergy 19/14 (Westway Feed Products, New Orleans, LA).

[2]Pelleted supplement contained the following (DM basis): 60.14% ground corn, 16.67% wheat middlings, 15.00% limestone, 1.67% urea, 4.16% salt, 1.67% magnesium oxide, 0.04% manganous oxide, 0.33% zinc sulfate, 0.07% vitamin A (30,000 IU/g), 0.04% vitamin E (50%), and 0.21% Rumensin 80 (Elanco Animal Health, Indianapolis, IN).

[3]All except DM presented on DM basis. DM presented as % of as-fed.

Table 6.2. Treatment and day effects of time spent below ruminal pH thresholds and above ruminal temperature thresholds in steers subjected to an acidosis challenge

	Treatment[1]				*P*-Values[2]		
Item	CON	HALF	CORN	SEM[3]	T	D	T×D
Time below ruminal pH of 5.5, min					0.03	0.002	<0.001
d 1	15.00	33.00	359.75[y]	161.34			
d 2	5.40[a]	50.67[a]	920.00[bz]	161.34			
d 3	15.66	0.00	421.50[y]	161.34			
Time below ruminal pH of 5.0, min					0.24	0.61	0.70
d 1	0.00	0.00	227.00	98.95			
d 2	0.00	0.00	121.50	98.95			
d 3	0.00	0.00	0.00	101.45			
Time above ruminal temperature of 39.0°C, min					0.87	0.36	0.74
d 1	294.75	355.67	272.25	165.34			
d 2	308.52	463.00	448.75	165.34			
d 3	456.14	489.33	319.50	165.34			
Time above ruminal temperature of 39.45°C, min					0.61	0.59	0.20
d 1	0.00	0.00	16.50	13.78			
d 2	0.00	8.33	32.00	13.78			
d 3	8.33	17.67	0.50	13.78			

[1]Acidosis challenge treatment: CON, no dietary change; HALF, half of daily DMI replaced with cracked corn; CORN, all of daily DMI replaced with cracked corn on d 1. All treatments were offered CON diet on d 2 and 3.
[2]Comparisons: T, treatment; D, day; T×D, interaction between T and D.
[3]Standard error of the mean.
[ab]Within a row, means without a common superscript differ ($P \leq 0.05$).
[yz]Within a column and item, means without a common superscript differ ($P \leq 0.05$).

Table 6.3. Correlations between ruminal pH, rectal temperature (RecT), and ruminal temperature (RumT) of steers subjected to an acidosis challenge

	Comparisons					
	RecT vs. RumT		pH vs. RecT		pH vs. RumT	
Item[1]	r	*P*-Value	r	*P*-Value	r	*P*-Value
CON						
d 1	0.65	<0.001	0.03	0.88	0.09	0.61
d 2	0.68	<0.001	-0.16	0.39	-0.18	0.33
d 3	0.43	0.01	-0.13	0.48	-0.46	0.01
HALF						
d 1	0.11	0.60	-0.02	0.93	-0.64	<0.001
d 2	0.03	0.90	-0.44	0.03	0.08	0.70
d 3	0.54	0.007	-0.25	0.24	0.03	0.88
CORN						
d 1	0.65	<0.001	-0.26	0.15	-0.63	<0.001
d 2	0.70	<0.001	-0.36	0.04	-0.33	0.06
d 3	0.63	<0.001	-0.34	0.06	-0.11	0.54

[1]Acidosis challenge treatment: CON, no dietary change; HALF, half of daily DMI replaced with cracked corn; CORN, all of daily DMI replaced with cracked corn on d 1. All treatments were offered CON diet on d 2 and 3.

Table 6.4. Correlations between times spent above ruminal temperature and below ruminal pH thresholds

	Comparisons[1]							
	TA39.0 vs. TB5.5		TA39.0 vs. TB5.0		TA39.45 vs. TB5.5		TA39.45 vs. TB5.0	
Treatment[2]	r	*P*-Value	r	*P*-Value	r	*P*-Value	r	*P*-Value
CON	-0.37	0.24	---	---	-0.16	0.61	---	---
HALF	0.33	0.38	---	---	-0.26	0.50	---	---
CORN	0.57	0.05	0.43	0.17	0.66	0.02	0.50	0.10

[1]Time Response variables: TA39.0 = time above ruminal temperature of 39.0°C; TA39.45 = time above ruminal temperature of 39.45°C; TB5.5 = time below ruminal pH of 5.5; TB5.0 = time below ruminal pH of 5.0.

[2]Treatments: CON, no dietary change; HALF, half of daily DMI replaced with cracked corn; CORN, all of daily DMI replaced with cracked corn on d 1. All treatments were offered CON diet on d 2 and 3.

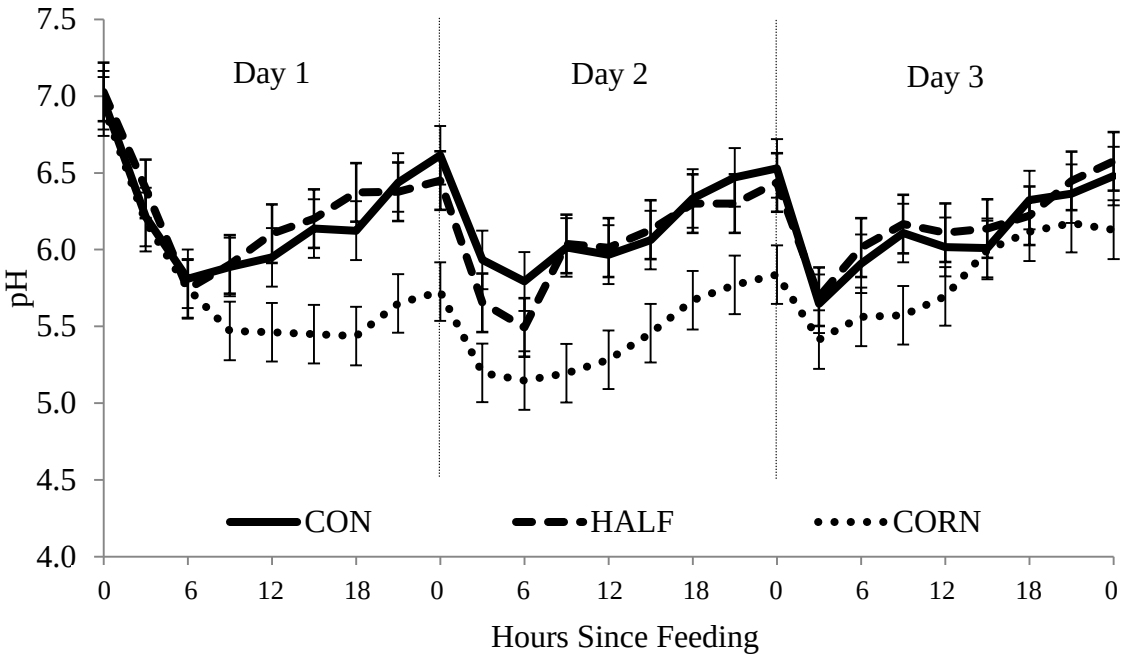

Figure 6.1. Ruminal pH of steers measured at 3 h sampling intervals across 3 d. Ruminally dosed acidosis challenge treatments: CON, no dietary change (n = 4); HALF, half of daily DMI replaced with cracked corn (n = 3); CORN, all of daily DMI replaced with cracked corn (n = 4). Vertical lines represent the starting points for d 1, 2, and 3. Main effects: Treatment ($P = 0.04$), d ($P < 0.01$); h from 0800 dosing (d 1) or feeding (d 2 and 3, $P < 0.01$). Interactions: Treatment × d ($P = 0.02$, SEM = 0.12), CORN < HALF ($P = 0.05$) on d 1, and CORN < HALF and CON ($P \leq 0.01$) on d 2; Treatment × h ($P = 0.47$), d × h ($P < 0.01$), treatment × d × h ($P = 0.59$).

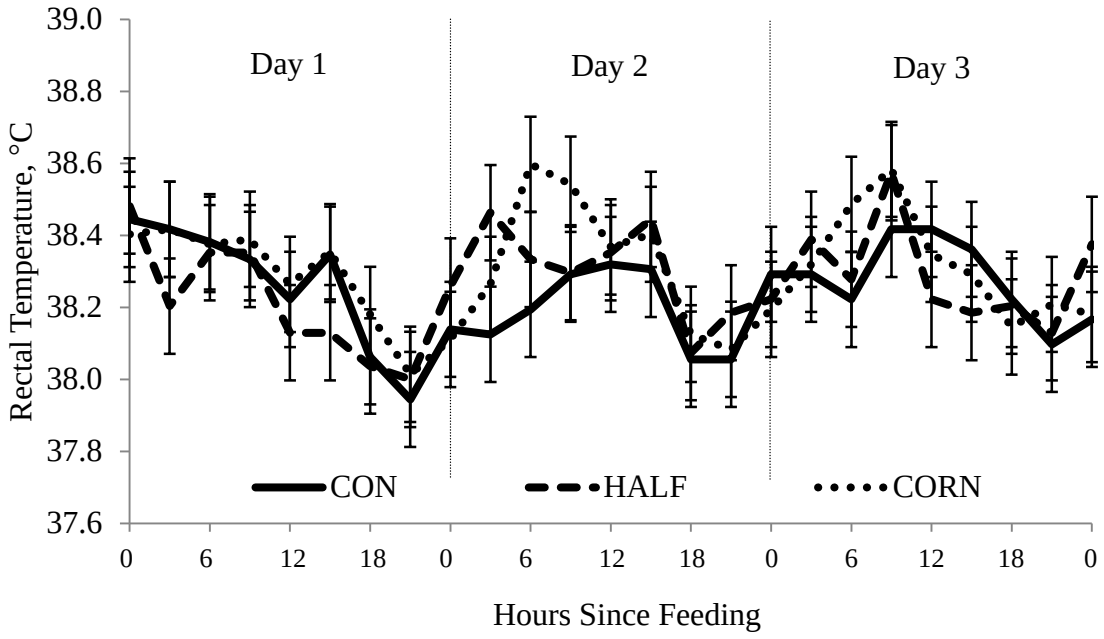

Figure 6.2. Rectal temperatures of steers measured at 3 h sampling intervals across 3 d. Ruminally dosed acidosis challenge treatments: CON, no dietary change (n = 4); HALF, half of daily DMI replaced with cracked corn (n = 3); CORN, all of daily DMI replaced with cracked corn (n = 4). Vertical lines represent the starting points for d 1, 2, and 3. Main effects: Treatment ($P = 0.79$), d ($P = 0.56$), h since 0800 dosing (d 1) or feeding (d 2 and 3, $P < 0.01$). Interactions: d × h ($P < 0.01$, SEM = 0.08), at h 0, d 1 > d 2 and 3 ($P \leq 0.007$), at h 9, d 1 and 2 < d 3 ($P = 0.03$), at h 21, d 1 < d 3 ($P = 0.04$); treatment × d ($P = 0.34$), treatment × h ($P = 0.22$), treatment × d × h ($P = 0.43$).

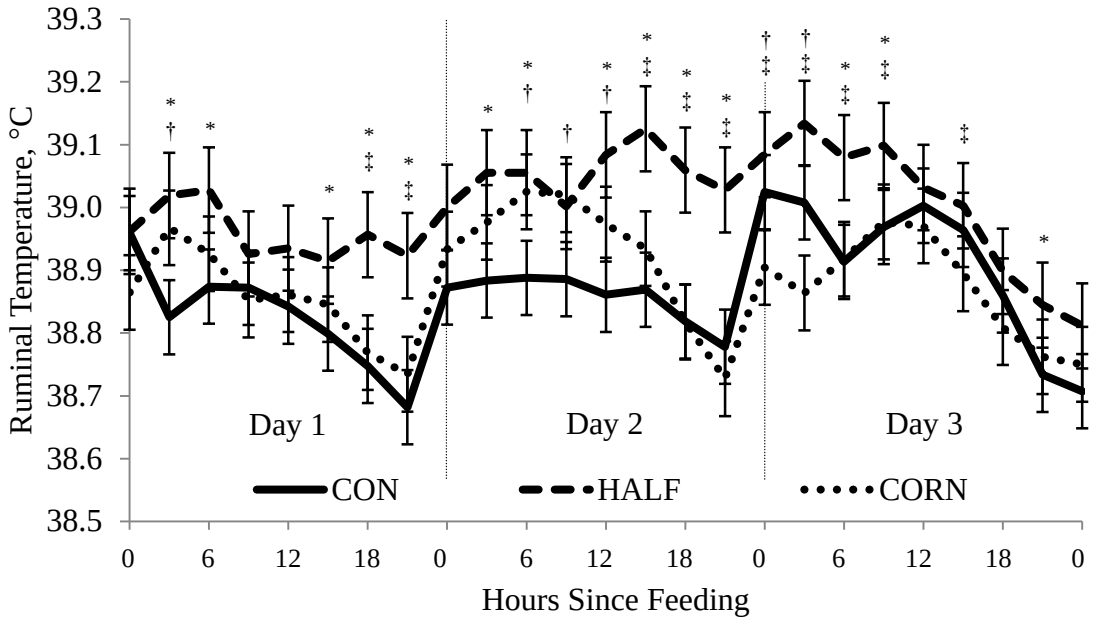

Figure 6.3. Ruminal temperatures of steers averaged over 3 h sampling intervals across 3 d. Ruminally dosed acidosis challenge treatments: CON, no dietary change (n = 4); HALF, half of daily DMI replaced with cracked corn (n = 3); CORN, all of daily DMI replaced with cracked corn (n = 4). Vertical lines represent the starting points for d 1, 2, and 3. Main effects: Treatment ($P < 0.01$), d ($P < 0.01$), h since 0800 dosing (d 1) or feeding (d 2 and 3, $P < 0.01$). There was a treatment × d × h interaction ($P < 0.01$, SEM = 0.07). *CON differs from HALF ($P \leq 0.05$), †CON differs from CORN ($P \leq 0.05$), ‡HALF differs from CORN ($P \leq 0.05$).

CHAPTER VII

ZILPATEROL HYDROCHLORIDE IMPACT ON CORE BODY TEMPERATURE, PERFORMANCE, AND CARCASS CHARACTERISTICS IN FEEDLOT CATTLE

ABSTRACT

This experiment evaluated the effect of zilpaterol hydrochloride (**ZH**) on body temperature of feedlot calves. Three groups of feedlot calves were utilized: 67 steers, 73 fall-finished heifers, and 163 spring-finished heifers in 2 weight blocks. Calves were randomly assigned to control (0 mg/kg ZH) or ZH (7.3 mg/kg ZH) diets. Ruminal temperatures were recorded using remote monitoring rumen boluses. Temperature decreases of at least 0.44°C between consecutive readings were interpreted as initiation of water drinking events. Temperatures and drink events were summarized daily by period: 1) prior to ZH inclusion, 7 d; 2) during ZH inclusion, 20 to 25 d; and 3) withdrawal period, 5 or 6 d. Calves offered ZH had greater ADG and G:F ($P \leq 0.05$), HCW ($P \leq 0.09$), dressing percent ($P < 0.01$), and LM area ($P < 0.01$), and lower yield grade ($P \leq 0.02$). Average daily ruminal temperature of steers and fall-finished heifers showed a treatment ×period interaction ($P \leq 0.03$). Temperatures of control steers increased by 0.10°C from period 1 to period 3, while average daily temperatures of ZH

steers remained steady between periods 1 and 2, and increased by 0.15°C during period 3. In fall-finished heifers, average daily temperatures of the control group decreased by 0.17°C from period 1 to period 2, and tended ($P = 0.07$) to decrease by 0.05°C from period 2 to period 3. Average daily temperatures of fall-finished heifers offered ZH decreased by 0.18°C from period 1 to period 2, but increased by 0.06°C from period 2 to period 3. Average daily temperatures of spring-finished heifers were not affected ($P \geq 0.15$) by treatment. Calculated area under daily temperature points associated with water consumption in fall-finished heifers and the heavy weight block of spring-finished heifers showed a treatment × period interaction ($P \leq 0.04$). In fall-finished heifers, area tended ($P = 0.06$) to be 0.34 units greater during period 2 compared with 1 in the control group, and was 0.55 units greater ($P < 0.01$) during period 2 compared with periods 1 and 3 in ZH heifers. In spring-finished heifers, area was 0.74 units greater ($P \leq 0.05$) in period 3 compared with periods 1 and 2 in control heifers, but area was not different ($P \geq 0.30$) among the 3 periods in ZH heifers. Area associated with water consumption was unaffected ($P \geq 0.37$) by ZH in all other groups of calves. Results indicate that ZH does not increase ruminal temperature or consistently affect drinking behavior of cattle.

KEY WORDS: beef cattle, beta-agonist, carcass, temperature, zilpaterol hydrochloride

INTRODUCTION

β-adrenergic agonists (**βAA**) are commonly used feed additives that improve feedlot performance and carcass traits of finishing beef cattle (Moloney et al., 1990; Chikhou et al., 1993). Zilpaterol hydrochloride (**ZH**) was approved in 2006 for inclusion in feedlot diets for the final 20 to 40 d prior to harvest with a 3 d withdrawal period (FDA, 2006). Zilpaterol hydrochloride has been shown to increase ADG, G:F, HCW,

dressing percent, and LM area, and to decrease yield grade while having no impact on 12th-rib fat thickness (Elam et al., 2009; Montgomery et al., 2009; Holland et al., 2010). β-adrenergic agonists bind to the same receptors as catecholamines, including epinephrine and norepinephrine, activating G_s proteins, facilitating a series of reactions that have multiple metabolic effects in cattle (Mersmann, 1998). In mammals, heart and respiration rates increase with feeding of βAA in response to dilated arterioles (Eiler, 2004). While these effects have been established in cattle (Bruckmaier and Blum, 1992), the effect of βAA on core body temperature in feedlot cattle has not been explored. We hypothesized that feeding a βAA would increase body temperature in cattle. The objective of this experiment was to determine the effect of feeding ZH on core body temperature of finishing cattle.

MATERIALS AND METHODS

All experimental procedures were approved by the Oklahoma State University Institutional Animal Care and Use Committee.

Cattle

This experiment was conducted on 3 groups of feedlot calves that were harvested in December, 2008; October, 2009; and March, 2010.

Steers. Sixty-eight British and British × *Bos indicus* steer calves (mean BW = 255 ± 35 kg) were delivered on June 1, 2008 to the Oklahoma State University Willard Sparks Beef Research Center (**WSBRC**; Stillwater, OK) from Baton Rouge, LA (1,088 km). Calves were allowed to rest for approximately 1 h after arrival, and were then individually weighed and administered electronic identification, and sequentially

numbered ear tags. Calves were then placed in 8 pens, and were allowed ad libitum access to long-stemmed prairie hay until initial processing on the following d. At initial processing, calves were dehorned, castrated when necessary, and administered a viral respiratory vaccine (Vista 5 SQ, Intervet/Schering-Plough, DeSoto, KS), a clostridial toxoid (Vision 7 with Spur, Intervet/Schering-Plough), and a deworming medication (Ivomec Plus Injectable, Merial, Duluth, GA). Eighteen steers were also administered a metaphylactic dose of tulathromycin (2.5 mg/kg BW; Draxxin, Pfizer Animal Health, Exaton, NY) as part of a separate receiving experiment protocol. Fourteen d post-processing, steers were revaccinated (Vista 5 SQ, Intervet/Schering-Plough) and implanted with 20 mg of estradiol, 200 mg of progesterone, and 29 mg of tylosin tartrate (Component E-S with Tylan, VetLife, West Des Moines, IA). At 102 d after arrival, steers were re-implanted with 120 mg of trenbolone acetate and 24 mg of estradiol (Revalor-S, Intervet/Schering-Plough).

After a 42-d receiving period and a 115-d growing period, steers were weighed on 2 consecutive d prior to initiation of treatment diets (mean BW = 552 ± 4 kg). Steers were stratified by coat color and mean BW and randomly assigned to 1 of 12 pens (n = 5 or 6 per pen). Steers receiving metaphylaxis were equally distributed among pens and experimental treatment groups.

Fall-finished heifers. One hundred twenty-four heifers (BW = 362 ± 30 kg) were purchased at an auction barn in El Reno, OK in May, 2009 and shipped 146 km to WSBRC in Stillwater, OK. Upon arrival, heifers were allowed to rest for approximately 1 h, and were then individually weighed and administered a unique identification ear tag.

The next d (initial processing), heifers were re-weighed, dehorned when necessary, and administered a viral respiratory vaccine (Vista 5 SQ, Intervet/Schering-Plough, DeSoto, KS), a clostridial toxoid (Vision 7 with Spur, Intervet/Schering-Plough), a deworming medication (Ivomec Plus Injectable, Merial), and an implant containing 140 mg trenbolone acetate and 14 mg estradiol (Revalor-H, Intervet/Schering-Plough). Heifers were stratified by coat color and mean BW and randomly assigned to 24 pens (5 or 6 heifers per pen). One heifer calved the next day and was removed from the project. Six d after initial processing, all heifers were pregnancy checked, 2 of which were confirmed pregnant and removed from the project. Removal of these heifers resulted in n = 4, 5, or 6 animals per pen. All heifers were revaccinated (Vista 5 SQ, Intervet/Schering-Plough) 14 d after initial processing. After a 115-d growing period, heifers were weighed prior to AM feeding of treatment diets (mean BW = 547 ± 5 kg).

Spring-finished heifers. One hundred sixty-seven British crossbred heifers (BW = 237 ± 20 kg) were assembled at an auction facility in Hillsboro, OH in September 2009. Heifers were assigned a unique identification ear tag at the facility, and were then transported 1,424 km to the WSBRC, Stillwater, OK. Upon arrival, heifers were allowed to rest for approximately 1 h before obtaining individual weights. At initial processing 2 d later, heifers were re-weighed, dehorned when necessary, and administered a viral respiratory vaccine (Express 5, Boehringer Ingelheim, St. Joseph, MO), a clostridial toxoid (Vision 7 with Spur, Intervet/Schering-Plough), a deworming medication (Ivomec Plus Injectable, Merial), and an implant containing 8 mg of estradiol and 40 mg of trenbolone acetate (Component TE-G, VetLife). Fifty-six heifers were also administered

an antimicrobial treatment of tulathromycin (2.5 mg/kg BW; Draxxin, Pfizer Animal Health) as part of a separate receiving experiment protocol. Heifers were stratified by coat color, blocked into 2 weight groups based on mean BW and randomly assigned to 12 pens (6 pens per block, 13 or 14 heifers per pen). Heifers were revaccinated with the viral respiratory vaccine 14 d later. At 68 d after arrival, all heifers were administered a second implant containing 80 mg trenbolone acetate and 8 mg estradiol (Revalor-IH, Intervet/Schering-Plough). At 124 d after arrival, the light weight block heifers were administered a third implant containing 140 mg trenbolone acetate and 14 mg estradiol (Revalor-H, Intervet/Schering-Plough). After a 56-d receiving period and a 96- or 115-d growing period (heavy and light weight blocks, respectively), heifers were weighed prior to AM feeding of treatment diets (mean BW = 482 ± 10 kg). Heifers were not reassigned to pens to maintain integrity of previous experimental treatments. Of the initial 167 heifers, 162 completed the experiment. Causes for removal included death due to BRD (n = 1), severe illness due to BRD (n = 2), lameness (n = 1), and injury (n = 1).

Experimental Treatments

Within cattle groups and weight blocks, pens were randomly assigned to 1 of 2 treatments. Treatments included 0 (control) or 7.3 mg/kg ZH (Zilmax, Intervet/Schering-Plough, 90% DM basis) fed for 20-25 d at the end of the finishing phase with a 5 or 6 d withdrawal period prior to harvest. Each treatment was assigned to 6 pens of steers, 12 pens of fall-finished heifers, and 6 pens of spring-finished heifers. For spring-finished heifers, ZH treatments were distributed evenly among previous experimental treatments. Steers and spring-finished heifers were housed in open-air, dirt-floor pens measuring 12.2

m × 30.5 m. Pens provided 62.02 or 74.43 m^2 of pen space and 2.03 or 2.44 m of bunk space per steer (6 or 5 steers per pen, respectively) and 26.6 or 28.6 m^2 of pen space and 0.87 or 0.94 m of bunk space per heifer (14 or 13 heifers per pen, respectively). Fall-finished heifers were housed in partially-covered pens measuring 4.57 m × 15.24 m, with a 4.57 m concrete apron extending into the pen from the bunk. Metal awnings covered bunks and aprons. Pens provided 11.61, 13.94, or 17.42 m^2 of pen space and 0.76, 0.91, or 1.14 m of bunk space per heifer (6, 5, or 4 heifers per pen, respectively). Calves were allowed ad libitum access to water via automatic water units (Johnson Concrete Cattle Waterers, #J360-F; Hastings, NE), which were located along the fence line, and shared between 2 adjacent pens.

Treatment diets (Table 7.1) were fed to steers for 20 d, to fall-finished heifers for 25 d, to the heavy weight block of spring-finished heifers for 21 d, and to the light weight block of spring-finished heifers for 23 d. After the treatment period, calves assigned to the ZH treatment were offered the same diet as calves assigned to the control treatment. Diets were sampled from the bunks after delivery once weekly during the ZH feeding period and composited over the period. Analysis of the samples revealed that no ZH was contained in the control diets, and that ZH diets contained an acceptable level of ZH (7.00 ± 0.49 mg/kg DM basis).

Ruminal Temperature Measurements

Steers and spring-finished heifers were administered a remote temperature monitoring ruminal bolus (Strategic Solutions International, LLC., Stillwater, OK) 1 wk prior to initiation of treatment diets using a custom balling gun. Fall-finished heifers

were administered boluses 71 d prior to initiation of treatment diets. Boluses remained permanently in the reticulum, and were programmed to transmit individual animal temperature data at a rate of once every 2 min via fixed transceiver stations, which were specifically designed to receive bolus signals, located above each water unit. Transceiver stations were also located above the middle of feed bunks of pens housing the steers and spring-finished heifers. Data were relayed to a fixed transceiver station equipped with a USB serial connection, which logged temperature data in a database on a personal computer. Temperatures were received by the computer at a mean rate of once every 6 ± 3.8 min per animal. A number of extra boluses were available and used to administer an additional bolus when a failure was identified. Data from 1 steer and 48 fall-finished heifers were omitted from the analysis, as these calves had multiple days of missing data during the pre-experimental period, experimental period, or both. After removal of fall-finished heifers, pens with less than 3 calves with complete temperature data remaining were eliminated from the analysis, resulting in 10 pens for each treatment group.

Temperatures less than 38.61°C were assumed to be associated with water drinking events, and were removed from the dataset prior to analysis of average and maximum daily temperatures. Dye and Richards (2008) monitored ruminal temperature and measured water intake in individually housed steers, and determined that an equation using time length of a water drinking event and maximum ruminal temperature decline best predicted volume of water consumed. A modification of this technique was utilized to estimate water intake. The area under the daily temperature points for each animal was calculated using the formula for area of a trapezoid. The current temperature and

previous temperature were used as the 2 bases, and the time between the 2 temperatures served as the amplitude of the trapezoid, with Julian time as the units for amplitude:

$$Area = time\ difference * (\frac{current\ temp. + previous\ temp.}{2})$$

Areas for all trapezoids within a d (0800 to 0759) were summed for each animal to determine the total area under the temperature points for each d. Additionally, area under temperature points greater than 38.61°C were calculated and summed within d to determine area not associated with water drinking events. This area subtracted from total area then represented the proportion of area associated with water drinking events.

The number of times within a d that calves consumed water was counted. The initiation of a water drinking event was identified when ruminal temperature decreased by at least 0.44°C between 2 consecutive readings. Additional decreases of at least 0.44°C that occurred within 30 min of the initial decrease were assumed to be associated with the same water drinking event, and were not counted.

Daily temperature and drink event data were summarized for each pen, and categorized into 1 of 3 time periods including: 1) Prior to ZH inclusion (7 d), 2) During ZH inclusion, and 3) Withdrawal period. Period 3 lasted 5 d for steers and 6 d for fall- and spring-finished heifers. Animals were shipped on the final d of period 3; therefore, complete daily data during this period were available for 4 d (steers) or 5 d (fall- and spring-finished heifers).

Carcass Traits

For steers, individual final live BW were recorded before AM feeding on the final d of the withdrawal period. Steers were transported that afternoon 443 km to a

commercial abattoir in Dodge City, KS, and were harvested the following morning. Final live BW of fall-finished heifers was recorded 3 d before transport 108 km away to a commercial abattoir located in Arkansas City, KS. Spring-finished heifers were weighed for the final time 2 d prior to transport to a commercial abattoir located 521 km away in Amarillo, TX. A 4% shrink was applied to final BW of all calves. At the harvest facilities, HCW was recorded, and after each plant's standard chill protocol, carcasses were ribbed at the 12th rib, and quality and yield grades and carcass traits were recorded. Carcass traits measured included marbling score, 12th-rib fat thickness, LM area, and percentage of internal fat (USDA, 1997). Dressing percent was calculated using a 4% shrunk final live BW. Carcass data were collected by trained personnel from Oklahoma State University.

Weather Data

Weather information was measured in 15-min intervals using a Wireless Vantage Pro2 weather station (Davis Instruments; Hayward, CA) that was located at the research facility. Temperature-humidity index (**THI**) measurements were calculated from temperature (°C) and relative humidity using the equation described by Amundson et al. (2006):

$$THI = (0.8 * temperature) + \left[\left(\frac{humidity}{100}\right) * (temperature - 14.4)\right] + 46.4$$

Daily maximum THI and daily minimum, maximum, and mean weather temperatures were then determined from the collected 15-min data.

Statistical Analysis

The steer and fall-finished heifer experiments were conducted as completely randomized designs, and the spring-finished heifer experiment was conducted as a completely randomized block design. The experimental unit was pen. Carcass adjusted final live BW was calculated as HCW/mean dressing percent for respective treatment within harvest group. Carcass adjusted ADG and G:F were calculated from carcass adjusted final live BW.

Animal performance, carcass traits, beef attributes, and temperature data were analyzed using the MIXED procedure of SAS (SAS Inst., Inc., Cary, NC). Quality grades were analyzed using the GLIMMIX procedure of SAS. The same models were used in both procedures. Treatment was the fixed effect for performance, carcass traits, and beef attributes. Treatment, period, and treatment × period were fixed effects for temperature data. The random effect for all analyses was pen within treatment. Block was also included as a random effect for data from spring-finished heifers. As blocks of spring-finished heifers were fed treatment diets at different times with differing environmental conditions, temperature data for these heifers were analyzed separately within block. Therefore, block was not included as a random variable in temperature analyses of these heifers. All temperature data were analyzed using repeated measures with a banded Toeplitz structure, with d as the repeated measure. Least squares means were calculated, and when means were different at the ($P \leq 0.10$) level, pairwise comparisons were performed using the PDIFF option of SAS. Differences are discussed when ($P \leq 0.05$), and considered tendencies when ($0.05 < P \leq 0.10$).

RESULTS

Performance, Intake, and Carcass Traits

Steers. Performance and intake data of steers are shown in Table 7.2. There were no treatment differences ($P \geq 0.18$) in initial or final BW; however, feeding ZH resulted in 0.25 kg/d greater ($P < 0.01$) ADG. Carcass adjusted BW was also not different ($P = 0.29$), while carcass adjusted ADG was improved ($P = 0.01$) by 0.26 kg/d with ZH inclusion. Dry matter intake was measured during each period, and across the entire experiment, with no treatment differences ($P \geq 0.58$) observed. As a result of the greater ADG in steers offered ZH, G:F of steers consuming ZH was 32.9% greater ($P < 0.01$), and carcass adjusted G:F was 33.3% greater ($P = 0.02$) compared with control.

Feeding ZH resulted in 15.7 kg greater ($P = 0.01$) HCW and 1.73 percentage units greater ($P < 0.01$) dressing percent. Marbling score and 12th rib fat thickness were not affected ($P \geq 0.36$) by ZH. Zilpaterol inclusion resulted in 6.65 cm^2 greater ($P < 0.01$) LM area, and decreased ($P = 0.03$) internal fat by 0.53 percentage units. The percentage of steers that graded Standard, Select, or Choice was not affected ($P \geq 0.80$) by ZH inclusion. Yield grade was decreased ($P = 0.02$) by 0.41 units in ZH steers compared with control.

Fall-finished heifers. Performance and intake data of fall-finished heifers are shown in Table 7.3. Initial BW was not different ($P = 0.82$) between the 2 treatments. Inclusion of ZH did not affect ($P \geq 0.34$) final BW or carcass adjusted final BW. Heifers fed ZH had 0.31 kg/d greater ($P = 0.05$) ADG and 0.35 kg/d greater ($P = 0.05$) carcass adjusted ADG compared with control heifers. Dry matter intake was not different ($P \geq$

0.34) during any of the 3 periods or across the entire experiment. Due to greater ADG, G:F and carcass adjusted G:F were increased ($P = 0.04$) in ZH heifers compared with control.

Inclusion of ZH resulted in 13.1 kg greater ($P = 0.02$) HCW and 1.97 percentage units greater ($P < 0.01$) dressing percent. Marbling score was decreased ($P = 0.01$) by 8.9% with ZH inclusion, while 12th-rib fat thickness was not affected ($P = 0.29$). Heifers offered ZH had 7.48 cm^2 greater ($P < 0.01$) LM area. No differences ($P = 0.45$) were observed in internal fat between the treatments. The percentage of heifers that graded USDA Standard were not different ($P = 0.38$); however, 18.68 percentage units more ZH heifers tended ($P = 0.07$) to grade USDA Select, and 22.17 percentage units fewer ($P = 0.03$) ZH heifers graded USDA Choice compared with control heifers. Yield grade of ZH heifers was decreased ($P = 0.02$) by 0.4 units compared with control.

Spring-finished heifers. Performance and intake data for spring-finished heifers are shown in Table 7.4. Heifers had been previously exposed to a separate experimental protocol during the receiving phase and were maintained in assigned pens for the finishing phase. While initial BW was not different ($P = 0.43$) among the control and ZH treatments, initial BW was a necessary covariate ($P < 0.01$) and used for analysis of BW, ADG, and G:F. Final BW was 1.8 kg greater ($P = 0.02$) in ZH heifers, and carcass adjusted BW tended ($P = 0.06$) to be 1.8 kg greater in ZH heifers compared with control. Average daily gain was increased ($P = 0.03$) by 0.07 kg/d in ZH heifers, and carcass adjusted ADG tended ($P = 0.07$) to increase by 0.07 kg/d as the result of ZH inclusion. During periods 1 and 2, DMI was not different ($P \geq 0.18$); however, during period 3,

heifers offered the ZH diet tended ($P = 0.09$) to consume 0.43 kg/d less than control. Intake across the entire experiment was not different ($P = 0.19$). Heifers offered the ZH diet had 25.0% greater ($P = 0.03$) G:F and tended ($P = 0.10$) to have 19.6% greater carcass adjusted G:F compared with control.

Similar to final performance traits, initial BW of spring-finished heifers was a necessary covariate ($P < 0.01$) for HCW. Heifers offered ZH tended ($P = 0.09$) to have 6.3 kg greater HCW compared with control. Dressing percent was increased ($P < 0.01$) by 0.97 percentage units with ZH inclusion. Marbling score and 12th-rib fat thickness were not different ($P \geq 0.13$) between treatments. Inclusion of ZH resulted in 5.1 cm^2 greater ($P < 0.01$) LM area compared with control, and internal fat tended ($P = 0.07$) to increase by 0.08 percentage units in ZH heifers compared with control. No differences ($P \geq 0.12$) were observed in quality grade. Yield grade of heifers fed ZH was decreased ($P < 0.01$) by 0.37 units compared with control.

Temperature Measurements

Steers. Average and maximum daily temperature data of all calves are shown in Table 7.5. There was an interaction ($P = 0.01$) between treatment and period for average daily temperature. Inclusion of ZH did not affect ($P \geq 0.13$) temperatures during any of the 3 periods. Among control steers, temperatures during period 3 were 0.10°C greater ($P < 0.01$) compared with period 1, while temperatures during period 2 did not differ ($P \geq 0.17$) from those in periods 1 or 3. Among ZH steers, average daily temperatures during periods 1 and 2 were not different ($P = 0.11$) while temperatures during period 3 were 0.15°C greater ($P < 0.01$) than those during periods 1 and 2. Maximum daily temperature

showed a period effect ($P < 0.01$), where temperatures increased as the experiment progressed. Maximum daily temperatures increased ($P = 0.05$) by 0.04°C from period 1 to period 2, and increased ($P = 0.02$) by 0.07°C from period 2 to period 3. Maximum daily temperatures were 0.10°C greater ($P < 0.01$) during period 3 compared with period 1.

The area under daily temperature points was calculated to quantify daily differences in ruminal temperatures across treatments and periods, as a greater total area is associated with greater total body heat. In steers, total area was not affected ($P \geq 0.11$) by treatment or period (Table 7.6). While no treatment or period differences ($P \geq 0.22$) were observed in area associated with drinking events, there was a period effect ($P < 0.01$) for the number of daily drinking events. During period 1, steers drank 0.48 more times per d ($P < 0.01$) compared with periods 2 and 3, which were not different ($P = 0.69$).

Ruminal temperature observation began on November 11, and the withdrawal period ended on December 16. Environmental temperatures during the experiment ranged from -10.2°C to 25.4°C, and maximum daily THI ranged from 26.7 to 69.5 (Figure 7.1). Temperatures were highly variable both within and across days, as is typical during the fall season in Oklahoma.

Fall-finished heifers. There was an interaction ($P = 0.03$, Table 7.5) of treatment and period for average daily temperature of fall-finished heifers. During periods 1 and 2, no differences ($P \geq 0.28$) were observed between the 2 treatments. However, during

period 3, average daily temperatures of ZH heifers were 0.07°C greater ($P = 0.05$) than control.

Among control heifers, temperatures decreased ($P < 0.01$) by 0.17°C from period 1 to period 2, and decreased ($P < 0.01$) by 0.22°C from period 1 to period 3. Average daily temperatures of control heifers tended ($P = 0.07$) to be 0.05°C higher in period 2 compared with period 3. Among ZH heifers, temperatures decreased ($P < 0.01$) by 0.18°C from period 1 to period 2. From period 2 to period 3, average daily temperatures of ZH heifers increased ($P = 0.05$) by 0.06°C; however, temperatures during period 3 were still 0.12°C less ($P < 0.01$) than average daily temperatures during period 1.

Maximum daily temperature of fall-finished heifers was not affected ($P = 0.79$) by inclusion of ZH. There was a period effect ($P < 0.01$) for maximum daily temperature as environmental temperatures decreased as the experiment progressed. Temperatures decreased ($P < 0.01$) by 0.27°C from period 1 to period 2, by 0.39°C from period 1 to period 3, and by 0.12°C from period 2 to period 3.

Total area under daily temperature points was also affected ($P < 0.01$) by period in fall-finished heifers (Table 7.6). Total area during period 1 was 0.15 units greater ($P < 0.01$) than in period 2, and 0.20 units greater ($P < 0.01$) than in period 3. Total area during period 2 was 0.06 units greater ($P = 0.05$) than in period 3. Treatment did not affect ($P = 0.77$) area under the diurnal temperature curve of fall-finished heifers.

Area associated with drinking events showed a treatment × period interaction ($P = 0.02$). Area did not differ ($P \geq 0.12$) between the treatments during any of the 3 periods. Among control heifers, area associated with water drinking events tended ($P = 0.06$) to be 0.34 units greater during period 2 compared with period 1. No differences ($P \geq 0.23$)

were observed between periods 1 and 3 or between periods 2 and 3 in control heifers. Among ZH heifers, area associated with water drinking events was 0.55 units greater ($P < 0.01$) during period 2 compared with periods 1 and 3, which were not different ($P = 0.45$).

The number of times heifers drank during the d was affected ($P < 0.01$) by period. Heifers consumed fewer drinks per d as the experiment progressed. Number of drinks decreased ($P = 0.03$) by 0.37 drinks per d from period 1 to period 2, and by 1.10 drinks per d from period 2 to period 3 ($P < 0.01$). Heifers drank 1.47 more ($P < 0.01$) times per d during period 1 compared with period 3.

Environmental temperatures and THI during the experiment are shown in Figure 7.2. Temperatures ranged from 1.8°C to 34.6°C, and maximum daily THI ranged from 50.7 to 83.0 during September 5 through October 12. Temperatures generally decreased as the experiment progressed, following the pattern of maximum daily temperatures and number of drinks per d.

The hottest day of the experiment was during period 2 (September 27). The maximum daily environmental temperature that day reached 34.6°C, which was the hottest temperature observed during any ZH feeding, and the maximum THI observed on that d was 81.3. Therefore, ruminal temperatures were compared between control and ZH heifers on this d to observe effects of ZH feeding during hot environmental conditions (Figure 7.3). First, mean temperatures were calculated in 3 h intervals, beginning at 0800. Data were then analyzed using the fixed effects of treatment, time interval, and the interaction between treatment and time interval. No differences ($P = 0.42$) were observed in ruminal temperature due to treatment. Ruminal temperatures

exhibit diurnal variation; therefore, differences were observed ($P < 0.01$) due to time interval, with hottest ruminal temperatures being observed at 2000, and coolest temperatures being observed at 0800. There was no interaction ($P = 0.35$) between treatment and time interval on this d.

Spring-finished heifers. The spring-finished heifers had been blocked by BW at receiving, and were therefore finished at 2 different times. As these heifers were offered ZH during different environmental conditions, ruminal temperature data were analyzed separately for each weight block. Heifers belonging to the heavy weight block did not exhibit differences in average daily ruminal temperature due to either treatment or period ($P \geq 0.58$, Table 7.5). Maximum daily temperature was also not affected ($P = 0.88$) by treatment for the heavy weight block, but did show a period effect ($P = 0.02$). Maximum daily temperatures increased ($P \leq 0.02$) by 0.15°C from period 1 to periods 2 and 3, which were not different ($P = 0.53$). Heifers belonging to the light weight block did not exhibit differences in average or maximum daily ruminal temperature as the result of treatment ($P \geq 0.38$) or period ($P \geq 0.23$).

For the heavy block of spring-finished heifers, total area under daily temperature points was affected ($P < 0.01$) by period (Table 7.6). Total area during period 1 was 0.15 units less ($P < 0.01$) than in periods 2 and 3, which were not different ($P = 0.23$). There was an interaction ($P = 0.04$) between treatment and period for area associated with drinking events in the heavy weight block of spring-finished heifers. Within each period, no differences ($P \geq 0.13$) were observed between treatments. Among control heifers, area associated with drinking events during period 3 was 0.74 units greater ($P \leq 0.05$)

than in periods 1 and 2, which were not different ($P = 0.32$). Among ZH heifers, period did not affect ($P \geq 0.30$) area associated with drinking events.

The number of times the heavy block of spring-finished heifers drank water during the d had a treatment × period interaction ($P = 0.02$). During period 2, ZH heifers tended ($P = 0.08$) to drink 0.55 more times per d than control. No treatment differences ($P \geq 0.38$) were observed during periods 1 and 3. Control heifers tended ($P = 0.08$) to drink 0.27 more times per d during period 2 compared with period 1. The number of times control heifers drank each d during period 3 was not different ($P \geq 0.11$) than periods 1 or 2. Heifers offered the ZH diet drank 0.66 more times per d during period 2 compared with periods 1 and 3, which were not different ($P = 0.26$).

For the light weight block of spring-finished heifers, total area under daily temperature points showed a treatment × period interaction ($P = 0.04$). During period 1, total area was 0.15 units greater ($P = 0.03$) in ZH heifers compared with control. The treatments did not differ ($P \geq 0.84$) during periods 2 or 3. Among control heifers, total area during period 2 was 0.10 units greater ($P = 0.02$) than in period 1. Total area of control heifers during period 3 tended ($P = 0.08$) to be 0.10 units greater than in period 1. No differences ($P = 0.84$) were observed between periods 2 and 3 in control heifers. Total area under daily temperature points was not affected ($P \geq 0.30$) by period in ZH heifers.

Period affected ($P \leq 0.01$) area associated with drinking events and number of drinks per d in the light weight block of spring-finished heifers. Area associated with drinks during period 3 was 0.62 units greater ($P < 0.01$) than in periods 1 and 2, which were not different ($P = 0.89$). Compared with period 1, heifers drank 0.57 more times per

d ($P < 0.01$) during period 2, and tended ($P = 0.08$) to drink 0.18 more times per d during period 3. Heifers drank 0.39 more times per d ($P < 0.01$) during period 2 compared with period 3.

Environmental temperatures during the experimental periods of the heavy and light weight blocks are shown in Figures 7.4 and 7.5, respectively. Minimum and maximum environmental temperatures from February 5 through March 10 were -7.5°C and 20.9°C, respectively, and maximum daily THI ranged from 35.2 to 65.5 during the experimental periods for heavy weight block heifers. Minimum and maximum environmental temperatures for February 24 through March 31 were -7.3°C and 31.6°C, respectively, and maximum daily THI ranged from 37.0 to 76.4 during the experimental periods for light weight block heifers. Environmental temperatures generally increased as the experiment progressed for both weight blocks of spring-finished heifers, which likely explains trends for higher maximum daily temperatures and increased drink frequency during the later periods.

DISCUSSION

Compared with control, calves offered ZH responded as expected with respect to performance, carcass traits, and WBSF. Average daily gains and G:F were improved with inclusion of ZH. Hot carcass weights and LM area were increased and yield grade was decreased in carcasses from calves fed ZH. Similar results have been reported with respect to live animal performance (Holland et al., 2010; Parr et al., 2011) and carcass traits (Elam et al., 2009; Montgomery et al., 2009) in cattle fed ZH. This along with

analysis from collected feed samples indicate that the product was properly fed and performed as expected in the animals utilized in this experiment.

These data indicate that cattle do not consistently consume greater quantities of water when ZH is included in the diet. The values presented represent relational indicators of water intake, rather than volume of intake, and should be interpreted as such. Guyer (1977) estimated volume of water consumed by 454 to 544 kg finishing cattle during the cooler months of November through March to range between 32.6 and 39.7 L/d. These volumes likely represent the quantity of water consumed by the steers and spring-finished heifers. Estimated volume of water consumed by 454 to 544 kg finishing cattle during September and October ranges from 45.4 to 60.6 L/d (Guyer, 1977), and these volumes likely represent the quantity of water consumed by the fall-finished heifers. The heavy weight block of spring-finished heifers drank more times per d during the ZH feeding period compared with periods when ZH was not included in the diet. However, it should be noted that number of times water is consumed does not necessarily indicate the volume of water consumed. Area under daily temperature points associated with water drinking events suggests there is little relationship between ZH and volume of water consumed.

Ruminal temperatures showed little effect due to the feeding of ZH. In steers, average ruminal temperatures of calves offered ZH increased from period 2 to period 3, while temperatures of control calves were unchanged. In fall-finished heifers, ruminal temperatures of both treatment groups decreased after period 1. However, average daily temperatures of control heifers remained stable from period 2 to period 3, while average daily temperatures of ZH heifers increased from period 2 to period 3. These results from

steers and fall-finished heifers could indicate that feeding ZH did not affect ruminal temperature, but slight increases may occur when the product is removed from the diet. In spring-finished heifers, treatment had no effect on ruminal temperature measurements. Mader (2003) indicated that cattle begin to exhibit physiological effects of increased environmental heat when THI rises above 70. More recently, Arias and Mader (2011) indicated that this threshold may be as low as 67.2 in high-producing feedlot cattle. The cattle in the current experiment did not experience extended periods of environmental conditions beyond these thresholds, particularly during the ZH feeding period. Therefore, these results must be interpreted considering that cattle were exposed to mostly thermal neutral conditions.

Little research has investigated the effects of βAA on body temperature of mammals. Clenbuterol has been shown to cause a dose-dependent increase in body temperature of rats (Mogilnicka et al., 1985). Chwalibog et al. (1996) fed increasing amounts of the βAA L-644,969 to bull calves, and did not observe an increasing response in heat production. Page et al. (2004) fed 200 mg/kg of clenbuterol or 200 or 800 mg/kg of ractopamine to growing mice, and determined that mice fed βAA did not exhibit changes in body temperature compared to a control group. Macías-Cruz et al. (2010) fed 10 mg/d of ZH to ewe lambs during hot environmental conditions and measured skin temperature at several locations on the body. Compared to control, skin temperature of ZH lambs was greater at the belly and the right flank, but was not different at the head and rump of the animal. Increased temperature at the belly was suggested to be related to greater rumen microbial activity, resulting in greater heat of fermentation. However, cattle used in the present study did not exhibit increased ruminal temperatures as the

result of ZH feeding. Therefore, it is unlikely that changes in skin temperature due to ZH feeding are related to increased ruminal fermentation.

Based on these results during varying moderate range environmental conditions and within the thermal neutral zone, ZH does not increase body temperatures of cattle. It is possible that in some instances body temperature is slightly suppressed. This is potentially caused by increased blood flow due to more rapid heart rates, resulting in greater heat dissipation. In conclusion, it appears that feeding ZH according to current label directions has little to no effect on body temperature of cattle under moderate conditions.

LITERATURE CITED

Amundson, J. L., T. L. Mader, R. J. Rasby, and Q. S. Hu. 2006. Environmental effects on pregnancy rate in beef cattle. J. Anim. Sci. 84:3415-3420.

Arias, R. A., and T. L. Mader. 2011. Environmental factors affecting daily water intake on cattle finished in feedlots. J. Anim. Sci. 89:245-251.

Bruckmaier, R. M. and J. W. Blum. 1992. Response of calves to treadmill exercise during beta-adrenergic agonist administration. J. Anim. Sci. 70:2809-2821.

Chikhou, F. H., A. P. Moloney, P. Allen, J. F. Quirke, F. H. Austin, and J. F. Roche. 1993. Long-term effects of cimaterol in Friesian steers: I. Growth, feed efficiency, and selected carcass traits. J. Anim. Sci. 71:906-913.

Chwalibog, A., K. Jensen, and G. Thorbek. 1996. Oxidation of nutrients in bull calves treated with β-adrenergic agonists. Arch. Anim. Nutr. 49:255-261.

Dye, T. D., and C. J. Richards. 2008. Effect of water consumption on rumen temperature. J. Anim. Sci. 86(E Suppl. 3):86. (Abstr.)

Eiler, H. 2004. Endocrine glands. Pages 621-669 in Duke's Physiology of Domestic Animals. W. O. Reece, ed. Cornell University Press, Ithaca, NY.

Elam, N. A., J. T. Vasconcenlos, G. Hilton, D. L. VanOverbeke, T. E. Lawrence, T. H. Montgomery, W. T. Nichols, M. N. Streeter, J. P. Hutcheson, D. A. Yates, and M. L. Galyean. 2009. Effect of zilpaterol hydrochloride duration of feeding on performance and carcass characteristics of feedlot cattle. J. Anim. Sci. 87:2133-2141.

FDA. 2006. Freedom of information summary. Original new animal drug application NADA 141-258. Zilmax (zilpaterol hydrochloride) Type A medicated article for cattle fed in confinement for slaughter. http://www.fda.gov/cvm/FOI/141-258o08102006.pdf. Accessed Feb. 15, 2009.

Guyer, P. Q. 1977. Water requirements for beef cattle (G77-372). University of Nebraska-Lincoln Extension. http://digitalcommons.unl.edu/cgi/viewcontent.cgi?article=1329&context=extensionhist&sei-redir=1#search="water+intake+in+cattle+by+season+guyer". Accessed March 18, 2011

Holland, B. P., C. R. Krehbiel, G. G. Hilton, M. N. Streeter, D. L. VanOverbeke, J. N. Shook, D. L. Step, L. O. Burciaga-Robles, D. R. Stein, D. A. Yates, J. P. Hutcheson, W. T. Nichols, and J. L. Montgomery. 2010. Effect of extended withdrawal of zilpaterol hydrochloride on performance and carcass traits in finishing beef steers. J. Anim. Sci. 88:338-348.

Macías-Cruz, U., F. D. Álvarez-Valenzuela, N. G. Torrentera, Olivera, J. V. Velázquez-Morales, A. Correa-Calderón, P. H. Robinson, and L. Avendaño-Reyes. 2010. Effect of zilpaterol hydrochloride on feedlot performance and carcass characteristics of ewe lambs during heat-stress conditions. Anim. Prod. Sci. 50:983-989.

Mader, T. L. 2003. Environmental stress in confined beef cattle. J. Anim. Sci. 81:E110-119.

Mersmann, H. J. 1998. Overview of the effects of beta-adrenergic receptor agonists on animal growth including mechanisms of action. J. Anim. Sci. 76:160-172.

Mogilnicka, E., V. Klimek, G. Nowak, and A. Czyrak. 1985. Clonidine and a β-agonists induce hyperthermia in rats at high ambient temperature. J. Neural Transm. 63:223-235.

Moloney, A. P., P. Allen, D. B. Ross, G. Olson, and E. M. Convey. 1990. Growth, feed efficiency and carcass composition of finishing Friesian steers fed the β-adrenergic agonist L-644,969. J. Anim. Sci. 68:1269-1277.

Montgomery, J. L., C. R. Krehbiel, J. J. Cranston, D. A. Yates, J. P. Hutcheson, W. T. Nichols, M. N. Streeter, R. S. Swingle, and T. H. Montgomery. 2009. Effects of dietary zilpaterol hydrochloride on feedlot performance and carcass characteristics of beef steers fed with and without monensin and tylosin. J. Anim. Sci. 87:1013-1023.

Page, K. A., D. L .Hartzell, C. Li, A. L. Westby, M. A. Della-Fera, M. J. Azain, T. D. Prinle, and C. A. Baile. 2004. β-Adrenergic receptor agonists increase apoptosis of adipose tissue in mice. Domest. Anim. Endocrin. 26:23-31.

Parr, S. L., K. Y. Chung, M. L. Galyean, J. P. Hutcheson, N. DiLorenzo, K. E. Hales, M. L. May, M. J. Quinn, D. R. Smith, and B. J. Johnson. 2011. Performance of finishing beef steers in response to anabolic implant and zilpaterol hydrochloride supplementation. J. Anim. Sci. 89:560-570.

USDA. 1997. Official United States Standards for Grades of Carcass Beef. Agric. Marketing Serv., USDA, Washington, DC.

Table 7.1. Ingredients and nutrient composition of diets

	Experiment					
	Steers		Fall Heifers		Spring Heifers	
	Treatment[1]		Treatment		Treatment	
Item	Control	ZH	Control	ZH	Control	ZH
Ingredient, %						
Dry-rolled corn	72.5	72.5	70.0	70.0	70.0	70.0
Corn WDGS	14.5	14.5	-	-	-	-
Corn DDGS	-	-	12.0	12.0	12.0	12.0
Ground prairie hay	6.0	6.0	6.0	6.0	6.0	6.0
Liquid supplement[2]	-	-	6.0	6.0	6.0	6.0
Control supplement[3]	7.0	-	6.0	-	6.0	-
ZH supplement[4]	-	7.0	-	6.0	-	6.0
Nutrient composition						
DM, %	71.57	71.73	79.95	80.33	77.75	78.72
CP, %	12.96	13.20	13.17	13.20	12.56	12.30
ADF, %	7.35	7.33	8.00	6.70	6.00	7.46
NDF, %	15.67	16.63	15.73	13.73	14.86	15.45
Ca, %	0.51	0.58	0.46	0.41	0.42	0.31
P, %	0.36	0.37	0.30	0.28	0.37	0.38
Zilpaterol HCl, mg/kg[5]	None	6.44	None	7.29	None	7.29

[1]Zilpaterol hydrochloride diet was formulated to contain 7.3 mg/kg (90% DM basis) of zilpaterol hydrochloride (ZH, Intervet/Schering-Plough, DeSoto, KS).

[2]Synergy 19/14 (Westway Feed Products, New Orleans, LA).

[3]Pelleted supplement contained the following (DM basis): Steers: 58.87% ground corn, 3.57% potassium chloride, 23.57% limestone, 8.57% urea, 3.57% salt, 0.07% manganous oxide, 0.19% zinc oxide, 1.00% magnesium oxide, 0.08% copper sulfate, 0.05% vitamin A, 0.03% vitamin E, 0.27% Rumensin 80 (Elanco Animal Health, Indianapolis, IN), and 0.16% Tylan 40 (Elanco Animal Health). Heifers: 45.65% ground corn, 16.67% wheat middlings, 3.33% urea, 25.83% limestone, 4.00% salt, 0.05% manganous oxide, 0.25% zinc sulfate, 1.83% potassium chloride, 1.67% magnesium oxide, 0.05% vitamin A, 0.04% vitamin E, 0.31% Rumensin 80, 0.19% Tylan 40, 0.13% MGA-200 (Pfizer Animal Health, Exaton, NY).

[4]Pelleted supplement contained the same ingredients as the Control supplement, but ZH premix (Intervet/Schering-Plough) replaced 0.25% of ground corn for steers, and replaced 0.29% of ground corn for heifers.

[5]Determined from laboratory analysis (Intervet Pharmaceutical Laboratory; Lawrence, KS).

Table 7.2. Effect of zilpaterol hydrochloride (ZH) on performance, intake, and carcass traits of steers

	Treatment			
Item	Control	ZH	SEM	*P*-Value
BW, kg				
Initial	552.4	551.2	3.9	0.83
Final	583.7	592.5	4.4	0.18
Final, carcass adjusted[1]	583.4	592.4	5.8	0.29
ADG, kg	0.78	1.03	0.04	<0.01
Carcass adjusted ADG, kg[2]	0.77	1.03	0.15	0.01
DMI, kg/d[3]				
Period 1	9.59	9.76	0.22	0.58
Period 2	10.03	9.99	0.16	0.86
Period 3	9.89	9.71	0.22	0.59
Overall	9.84	9.87	0.13	0.87
G:F	0.079	0.105	0.004	<0.01
Carcass adjusted G:F[2]	0.078	0.104	0.007	0.02
HCW, kg	369.7	385.4	3.7	0.01
Dressing %	63.32	65.05	0.32	<0.01
Marbling score[4]	379.1	379.1	11.7	0.99
12th-rib fat thickness, cm	1.83	1.70	0.08	0.36
LM area, cm^2	78.06	84.71	1.10	<0.01
Internal fat, %	3.03	2.50	0.15	0.03
Quality grade, %				
Standard	0.00	2.94	2.90	0.98
Select	67.65	64.71	8.20	0.80
Choice	32.35	32.35	8.02	0.99
Yield grade	4.12	3.71	0.11	0.02

[1]Calculated as HCW/average dress for each treatment.

[2]Calculated based on carcass adjusted final BW.

[3]Period 1, prior to ZH inclusion (7 d); Period 2, During ZH inclusion (20 d); Period 3, Withdrawal period (5 d).

[4]300 = slight[00], 400 = small[00].

Table 7.3. Effect of zilpaterol hydrochloride (ZH) on performance, intake, and carcass traits of fall-finished heifers

	Treatment			
Item	Control	ZH	SEM	*P*-Value
BW, kg				
Initial	547.7	546.0	5.3	0.82
Final	559.5	566.5	5.0	0.34
Final, carcass adjusted[1]	561.6	564.7	5.7	0.70
ADG, kg	0.44	0.75	0.10	0.05
Carcass adjusted ADG, kg[2]	0.45	0.80	0.12	0.05
DMI, kg/d[3]				
Period 1	10.92	10.59	0.25	0.34
Period 2	10.16	10.25	0.23	0.79
Period 3	10.25	10.37	0.32	0.78
Overall	10.15	10.23	0.24	0.82
G:F	0.042	0.072	0.010	0.04
Carcass adjusted G:F[2]	0.043	0.077	0.011	0.04
HCW, kg	364.0	377.1	3.8	0.02
Dressing %	64.83	66.80	0.24	<0.01
Marbling score[4]	425.3	387.4	9.2	0.01
12th-rib fat thickness, cm	1.55	1.42	0.08	0.29
LM area, cm^2	88.13	95.61	1.55	<0.01
Internal fat, %	2.37	2.28	0.08	0.45
Quality grade, %				
Standard	1.96	5.46	3.06	0.38
Select	43.14	61.82	6.96	0.07
Choice	54.90	32.73	6.97	0.03
Yield grade	3.16	2.76	0.12	0.02

[1]Calculated as HCW / average dress for each treatment.

[2]Calculated based on carcass adjusted final BW.

[3]Period 1, prior to ZH inclusion (7 d); Period 2, During ZH inclusion (25 d); Period 3, Withdrawal period (6 d).

[4]300 = slight[00], 400 = small[00], 500 = modest[00].

Table 7.4. Effect of zilpaterol hydrochloride (ZH) on performance, intake, and carcass traits of spring-finished heifers

	Treatment			
Item	Control	ZH	SEM	*P*-Value
BW, kg				
Initial	484.3	480.5	9.8	0.43
Final*	492.0	493.8	1.1	0.02
Final, carcass adjusted[1*]	492.1	493.9	1.8	0.06
ADG, kg*	0.38	0.45	0.05	0.03
Carcass adjusted ADG, kg[2*]	0.39	0.46	0.07	0.07
DMI, kg/d[3]				
Period 1	9.14	8.65	0.21	0.79
Period 2	8.67	8.19	0.24	0.18
Period 3	8.41	7.98	0.16	0.09
Overall	8.73	8.34	0.20	0.19
G:F*	0.044	0.055	0.005	0.03
Carcass adjusted G:F[2*]	0.046	0.055	0.008	0.10
HCW, kg*	311.0	317.3	1.2	0.09
Dressing %	63.23	64.20	0.29	<0.01
Marbling score[4]	427.0	412.8	10.6	0.37
12th-rib fat thickness, cm	1.22	1.09	0.08	0.13
LM area, cm^2	80.19	85.29	0.65	<0.01
Internal fat, %	1.57	1.65	0.08	0.07
Quality grade, %				
No Roll	0.73	1.52	2.49	0.56
Select	28.00	39.88	6.46	0.20
Choice	69.51	56.26	5.76	0.12
Prime	0.94	0.97	1.44	0.99
Yield grade	2.39	2.02	0.07	<0.01

[1]Calculated as HCW / average dress for each treatment.

[2]Calculated based on carcass adjusted final BW.

[3]Period 1, prior to ZH inclusion (7 d); Period 2, During ZH inclusion(21 and 23 d for heavy and light weight blocks, respectively); Period 3, Withdrawal period (6 d).

[4]400 = small[00], 500 = modest[00].

*Initial BW used as a covariate ($P \leq 0.05$).

Table 7.5. Effect of period and zilpaterol hydrochloride (ZH) inclusion on average and maximum daily ruminal temperatures, °C

	Period[1]									
	1		2		3			*P*-Values[2]		
Experiment	Control	ZH	Control	ZH	Control	ZH	SEM	T	P	T×P
Steers										
Average daily temperature	39.67[a]	39.63[a]	39.74[ab]	39.67[a]	39.77[b]	39.80[b]	0.04	0.52	<0.01	0.01
Maximum daily temperature[3]	40.24	40.20	40.27	40.23	40.31	40.34	0.05	0.74	<0.01	0.35
Fall-finished heifers										
Average daily temperature	39.61[c]	39.58[c]	39.44[ab]	39.40[a]	39.39[a]	39.46[b]	0.04	0.91	<0.01	0.03
Maximum daily temperature[4]	40.34	40.30	40.09	40.01	39.90	39.97	0.07	0.79	<0.01	0.11
Spring-finished heifers, heavy weight block										
Average daily temperature	39.53	39.50	39.51	39.49	39.46	39.51	0.03	0.92	0.58	0.22
Maximum daily temperature[5]	39.94	39.88	40.05	40.10	40.03	40.06	0.06	0.88	0.02	0.49
Spring-finished heifers, light weight block										
Average daily temperature	39.44	39.45	39.45	39.43	39.37	39.40	0.05	0.84	0.32	0.15
Maximum daily temperature	39.96	40.00	39.98	40.01	39.83	39.92	0.10	0.38	0.23	0.77

[1]Period 1, Prior to ZH inclusion; Period 2, During ZH inclusion; Period 3, Withdrawal period.

[2]Comparisons: T, treatment; P, period; T×P, interaction between T and P.

[3]Period 1 < Period 2, Period 1 < Period 3, Period 2 < Period 3 ($P < 0.05$).

[4]Period 1 > Period 2, Period 1 > Period 3, Period 2 > Period 3 ($P < 0.05$).

[5]Period 1 < Period 2, Period 1 < Period 3 ($P < 0.05$).

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

Table 7.6. Effect of period and zilpaterol hydrochloride (ZH) inclusion on daily area under temperature points and water drinking behavior

	Period 1[1]		Period 2		Period 3			*P*-Values[2]		
Item	Control	ZH	Control	ZH	Control	ZH	SEM	T	P	T×P
Steers										
Area, time × °C										
Total	39.23	39.19	39.17	39.15	39.22	39.28	0.11	0.99	0.11	0.63
Area associated with drinks	2.33	2.43	2.30	2.32	1.94	2.25	0.22	0.48	0.22	0.63
Drinks, n[3,4]	3.56	3.83	3.07	3.33	3.19	3.29	0.25	0.54	<0.01	0.62
Fall-finished heifers										
Area, time × °C										
Total[*]	39.25	39.28	39.15	39.08	39.07	39.06	0.06	0.77	<0.01	0.23
Area associated with drinks	2.59[ab]	2.62[ab]	2.93[bc]	3.10[c]	2.82[abc]	2.49[a]	0.19	0.82	<0.01	0.02
Drinks, n[3,4,5]	5.43	5.59	5.09	5.19	3.93	4.14	0.26	0.62	<0.01	0.96
Spring-finished heifers, heavy weight block										
Area, time × °C										
Total[3,4]	38.78	38.70	38.93	38.81	38.89	38.95	0.06	0.18	<0.01	0.08
Area associated with drinks	2.78[a]	3.23[ab]	3.12[a]	3.54[ab]	3.70[b]	3.28[ab]	0.46	0.60	0.32	0.04
Drinks, n	3.36[a]	3.61[a]	3.64[ab]	4.19[b]	3.61[a]	3.45[a]	0.18	0.41	<0.01	0.02
Spring-finished heifers, light weight block										
Area, time × °C										
Total	38.73[a]	38.87[b]	38.83[b]	38.83[ab]	38.83[ab]	38.82[ab]	0.09	0.40	0.59	0.04
Area associated with drinks[4,5]	3.75	3.39	3.63	3.54	4.19	4.20	0.30	0.63	<0.01	0.37
Drinks, n[3,5]	3.88	3.93	4.39	4.55	4.12	4.06	0.14	0.79	<0.01	0.53

[1]Period 1, Prior to ZH inclusion; Period 2, During ZH inclusion; Period 3, Withdrawal period.

[2]Comparisons: T, treatment; P, period; T×P, interaction between T and P.

[3]Period 1 differs from Period 2 ($P < 0.05$).

[4]Period 1 differs from Period 3 ($P < 0.05$).

[5]Period 2 differs from Period 3 ($P < 0.05$).

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

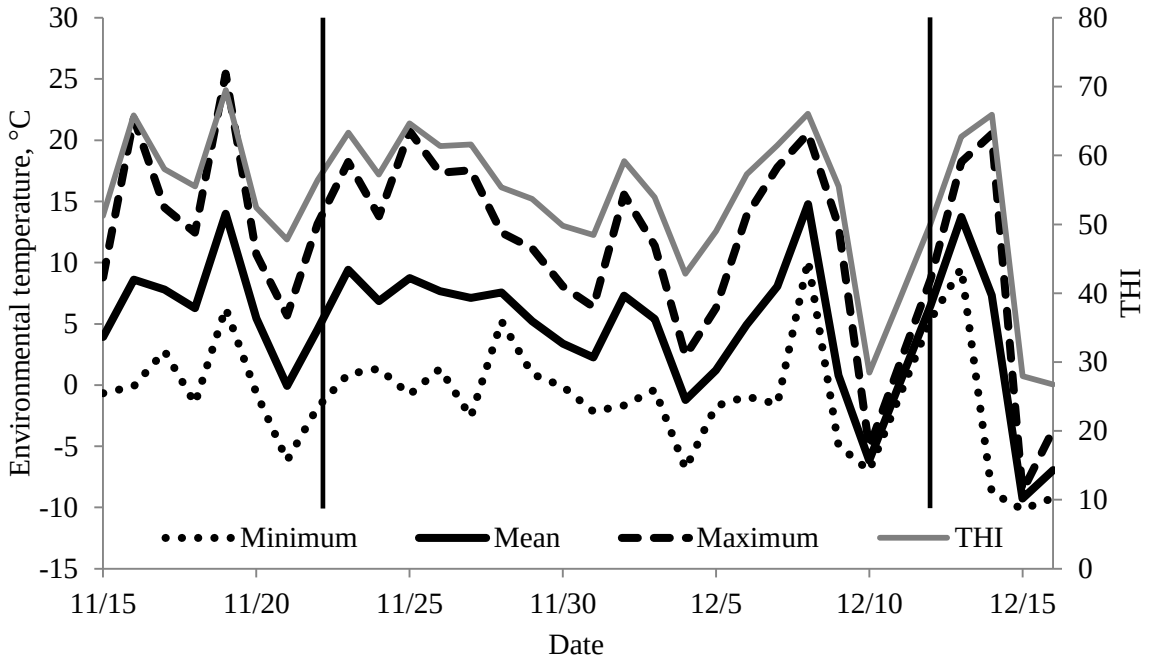

Figure 7.1. Daily minimum, mean, and maximum environmental temperatures (°C) and maximum daily temperature-humidity index (THI) during experimental periods for steers. Vertical lines represent divisions between experimental time periods. Period 1 = Prior to zilpaterol hydrochloride (ZH) inclusion, period 2 = During ZH inclusion, period 3 = Withdrawal period.

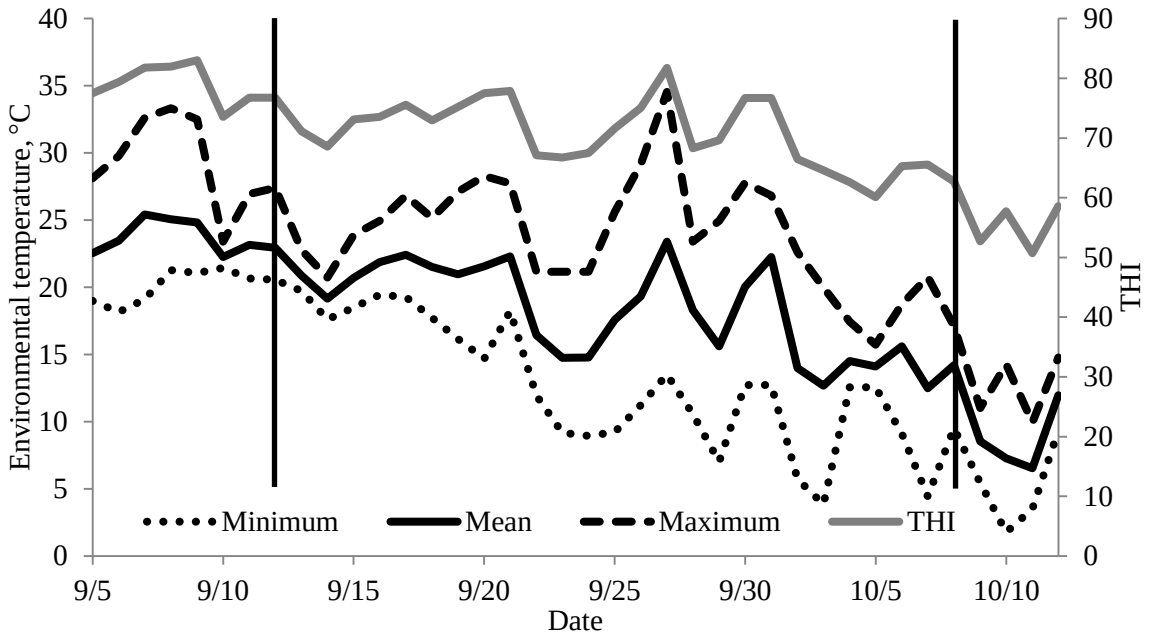

Figure 7.2. Daily minimum, mean, and maximum environmental temperatures (°C) and maximum daily temperature-humidity index (THI) during experimental periods for fall-finished heifers. Vertical lines represent divisions between experimental time periods. Period 1 = Prior to zilpaterol hydrochloride (ZH) inclusion, period 2 = During ZH inclusion, period 3 = Withdrawal period.

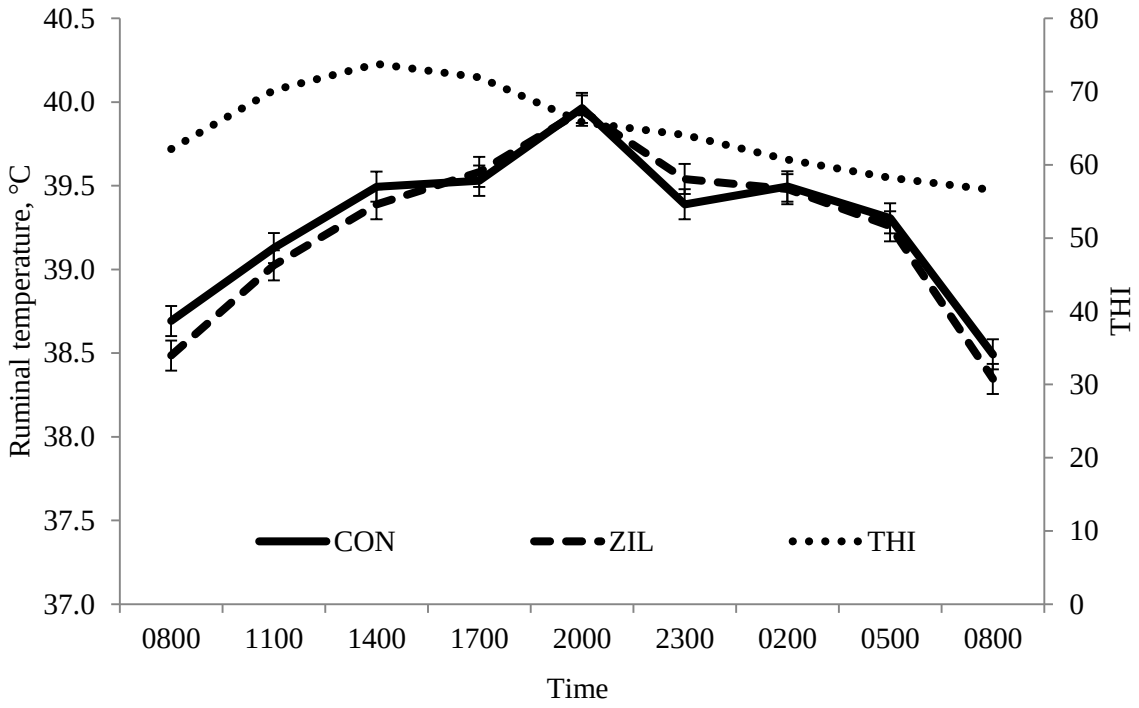

Figure 7.3. Ruminal temperatures of fall-finished heifers and temperature-humidity index (THI) beginning at 0800 on 9/27/2009, the hottest d of the experiment. Effect of treatment, $P = 0.42$; effect of time, $P < 0.01$; interaction between treatment and time, $P = 0.35$.

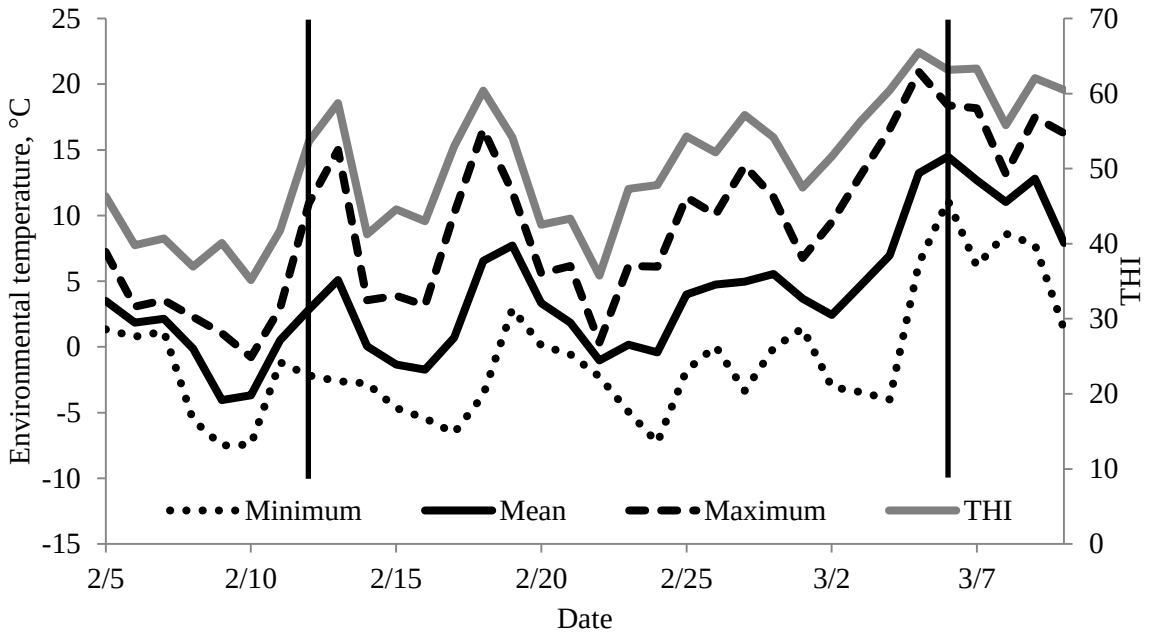

Figure 7.4. Daily minimum, mean, and maximum environmental temperatures (°C) and maximum daily temperature-humidity index (THI) during experimental periods for the heavy weight block of spring-finished heifers. Vertical lines represent divisions between experimental time periods. Period 1 = Prior to zilpaterol hydrochloride (ZH) inclusion, period 2 = During ZH inclusion, period 3 = Withdrawal period.

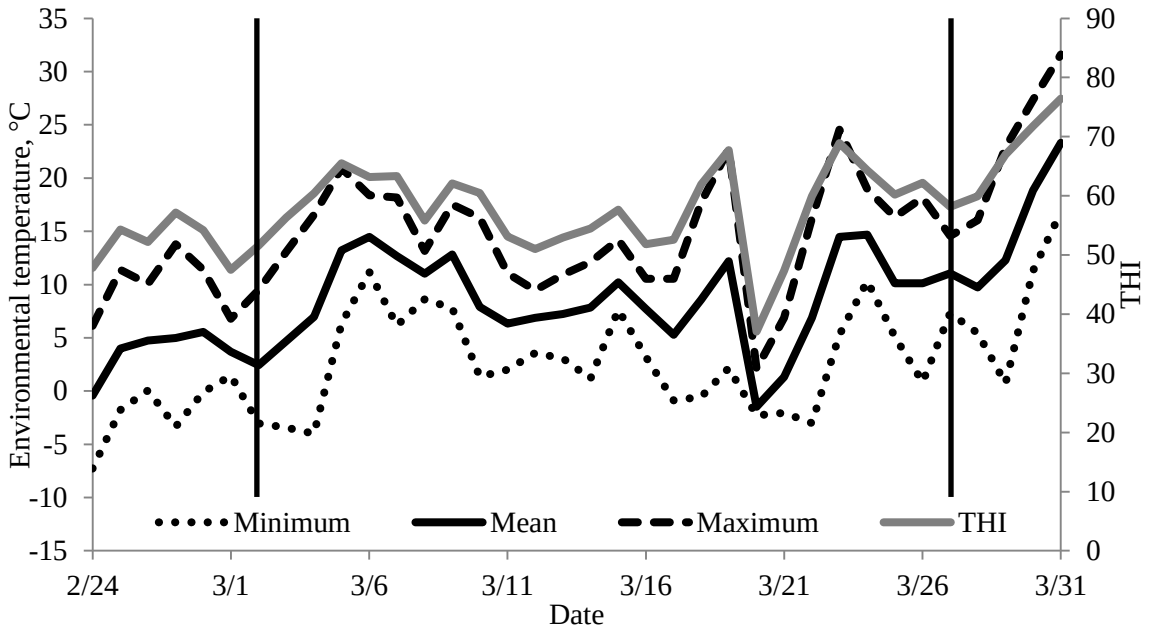

Figure 7.5. Daily minimum, mean, and maximum environmental temperatures (°C) and maximum daily temperature-humidity index (THI) during experimental periods the light weight block of spring-finished heifers. Vertical lines represent divisions between experimental time periods. Period 1 = Prior to zilpaterol hydrochloride (ZH) inclusion, period 2 = During ZH inclusion, period 3 = Withdrawal period.

VITA

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Thesis: REMOTE RUMINAL TEMPERATURE MONITORING IN FEEDLOT CATTLE: EFFECTS OF BOVINE RESPIRATORY DISEASE, RUMINAL ACIDOSIS, AND INCLUSION OF DIETARY β-ADRENERGIC AGONISTS

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Pages in Study: 226 Candidate for the Degree of Doctor of Philosophy

Major Field: Animal Nutrition

Ruminal temperature monitoring has potential as a useful tool to detect physiological changes in cattle resulting from illness and dietary changes. Heifer calves (n = 366, mean initial BW = 243 ± 30 kg) were assigned to one of three experimental management methods: Pulled based on visual signs of bovine respiratory disease (BRD, CON), administered metaphylaxis on d 0 and subsequently pulled based on visual signs of BRD (MET), or pulled based on visual signs of BRD or elevated ruminal temperature (TEMP). Overall ADG generally decreased as number of times identified with BRD increased; however, overall ADG of TEMP heifers did not differ ($P \geq 0.60$) among those identified with BRD zero, one, or two times. Heifers identified with BRD twice began the finishing phase weighing 16.9 kg less ($P < 0.01$) than all others. Final BW of CON heifers identified with BRD twice was 37.5 kg less ($P < 0.01$) than CON heifers never identified, while number of times identified with BRD did not affect ($P \geq 0.13$) final BW of TEMP and MET heifers. Carcasses from CON heifers identified with BRD twice were valued at $92 less ($P \leq 0.02$) than those from other CON heifers, while carcass value of TEMP and MET heifers was not affected ($P \geq 0.27$) by number of times identified with BRD. To determine if temperature monitoring can detect ruminal acidosis, twelve ruminally cannulated steers (518 ± 28 kg) were assigned to one of three acidosis challenge treatments: no dietary change (CON), half of daily DMI replaced with cracked corn (HALF), or all of daily DMI replaced with cracked corn (CORN). Ruminal pH was negatively correlated ($P \leq 0.02$) with ruminal pH in HALF and CON steers on d 1 and 3, respectively. The amount of time above ruminal temperature of 39.0 or 39.45°C was correlated ($P \leq 0.05$) with time spent below a ruminal pH of 5.5 in CORN steers. To determine if body temperature is affected by dietary inclusion of ZH, 67 steers, 73 fall-finished heifers, and 163 spring-finished heifers were assigned to control or ZH (7.3 mg/kg ZH) diets. Experimental periods included prior to (1) and during (2) ZH inclusion, and the withdrawal period (3). Temperatures of control steers increased by 0.10°C from period 1 to period 3, while temperatures of ZH steers remained steady between periods 1 and 2, and increased by 0.15°C during period 3. In fall-finished heifers, temperatures of control calves decreased by 0.17°C from period 1 to period 2, and tended ($P = 0.07$) to decrease by 0.05°C from period 2 to period 3. Temperatures of fall-finished heifers offered ZH decreased by 0.18°C from period 1 to period 2, but increased by 0.06°C from period 2 to period 3. Temperatures of spring-finished heifers were not affected ($P \geq 0.15$) by treatment. Results indicate that metaphylaxis and ruminal temperature monitoring may assist in identification of subclinical BRD, that temperature monitoring may have the ability to detect ruminal temperature changes that correspond with declining ruminal pH, and that ZH does not increase ruminal temperature.

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