MONITORING RUMEN TEMPERATURE AS AN INDICATOR OF RECEIVING CALF HEALTH

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TABLE OF CONTENTS

LIST OF TABLES

Table Page

LIST OF FIGURES

Figure Page

CHAPTER I

INTRODUCTION

Respiratory disease costs the feedlot industry hundreds of millions of dollars each year due to labor, treatment costs, decreased performance, and mortality (Griffin, 1997). Bovine Respiratory Disease (BRD) presents the most significant health issue to North American feedlots and is responsible for 70% to 80% of total morbidity and 40% to 50% of mortality (Smith, 1998). Producers are constantly searching for ways to prevent and treat BRD to maintain healthy cattle. Cattle that are not healthy require more input costs resulting in less profit for producers. Identifying animals infected with BRD before clinical signs appear would be beneficial for reducing treatment costs and increasing profitability for producers.

The most common method for monitoring animal health in the feedlot industry is through visual appraisal. Once an animal is identified as potentially sick, it is moved to a working facility for further examination where rectal temperature is measured. Rectal temperature is the industry standard as an objective method of health evaluation. It is relatively easy to measure and can be taken in a matter of a few seconds. Continuous, remote temperature monitoring systems are capable of automatically recording and transmitting an animal's core body temperature without having to move the animal into a chute. Remote temperature monitoring could detect potentially sick animals before they

begin showing visual symptoms and prevent the unnecessary handling of animals that do not have elevated temperatures.

Various types of remote or continuous temperature monitoring systems have been tested to verify their ability to determine body temperature. Much of the previous work has observed the effects of ambient temperature and stress on the animal's body temperature. Rumen, tympanic, and peritoneal cavity temperatures were typically compared to rectal temperature to assess accuracy and precision of the various methods.

The rumen is a unique environment for monitoring core body temperature. Water intake, fermentation of feedstuffs, and location of a rumen temperature bolus may have notable effects on measuring an animal's core body temperature from the rumen. A rumen temperature bolus has the advantage over other methods in that it is easily administered, it poses no threat to the animal, and there are very few concerns with lack of retention in the rumen.

While changes in temperature related to water intake levels, water temperature, and type of diet consumed may create challenges for determining average temperatures, they may also provide benefits. Information about feeding and watering behavior of cattle can lead to better health management of sick animals. An animal that spends less time eating and drinking compared to an animal that is known to be healthy could indicate illness.

A rumen temperature bolus can be programmed to collect data at various time intervals making it possible to detect and monitor sudden or gradual changes to the

ruminal environment. As a developing technology it has the potential to be a reliable management tool in the feedlot industry. However, the efficacy of the rumen temperature bolus in commercial settings must be determined.

This thesis includes an experiment that evaluates the use of rumen temperature boluses to monitor health status in newly received cattle that are at a high risk for developing BRD.

CHAPTER II

REVIEW OF LITERATURE

Introduction

Prevention of bovine respiratory disease (BRD) in feedlot cattle continues to be a primary concern in the industry. There have been significant advancements in the past two decades in regards to treatment of infected animals. However, the costs of producing quality beef products can increase when animals require treatment upon BRD diagnosis. Animals affected by BRD also perform poorly and have less valuable carcasses (Schneider et al., 2009; Snowder et al., 2006). Not only is early detection and identification of infected animals imperative to lessening the economic consequences of the disease, it can prevent transmission to other animals. There are management tools that could possibly supplement current detection strategies to aid in the prevention of BRD. Technologies to monitor body temperature are currently available and may be capable of early detection of sick animals.

Feedlot Calf Health

Introduction

Performance parameters such as ADG and G:F are closely monitored during the feeding phase of feedlot cattle to measure growth and estimate when cattle will be harvested. Cattle that are not healthy will not perform well and may require greater days

on feed compared to healthy animals. This increases feed costs, thus decreasing profitability of producers. It is crucial that feedlot producers maintain healthy herds throughout the feeding period. This requires them to manage newly received cattle very closely to detect and treat animals affected by BRD.

High Risk Receiving Cattle

Cattle entering the feedlot are faced with a substantial amount of stress that classifies them as being at risk for developing respiratory disease. There are a variety of preweaning and postweaning factors that contribute to the onset of BRD. Stresses due to weaning, marketing, transportation, previous plane of nutrition, genetics, and health history interact with exposure to viral and bacterial agents (Duff and Galyean, 2007). Typical marketing practices in the beef cattle industry can result in nutritional deficiencies, exposure to pathogens when commingled with calves from various sources, and changes in diet and feed intake (Step et al., 2008). Therefore, newly received cattle require a great deal of management upon the first few days of arrival.

Arthington et al. (2008) conducted a study that compared four weaning management strategies: 1) control: weaned the day of shipping; 2) creep-fed; allowed free-choice access to concentrate before weaning and shipping; 3) preweaned: weaned and provided supplemental concentrate on pasture before shipping; and 4) early-weaned: weaned at 70 to 90 d of age and kept on pasture. Over a 29-d receiving period, early-weaned calves had a greater ADG compared to control calves (Arthington et al., 2008). Arthington et al. (2008) also reported that in the first week of receiving, early-weaned

calves consumed more concentrate compared with control calves and preweaned calves consumed more concentrate than creep-fed calves. Also, early-weaned calves had a greater G:F compared with control calves, whereas there was no difference in feed efficiency among creep-fed and preweand calves (Arthington et al., 2008). Arthington et al. (2008) concluded that early-weaned calves perform more favorably in the feedlot compared with calves weaned directly before transport and feedlot entry.

Step et al. (2008) reported no difference in ADG among calves with different weaning management over a 42-d receiving period. However, in the last two weeks of the receiving period calves that had been weaned and on pasture for 45 d had greater ADG compared with calves that were weaned and immediately shipped to the feedlot. For the first 28 d calves that were weaned and immediately shipped had greater G:F than the calves on the other treatments and for the last 13 d the same group had lesser G:F than calves on the other treatments (Step et al., 2008). However, Step et al. (2008) observed that G:F did not differ among weaning protocols across the 42-d receiving period.

Bovine Respiratory Disease

There are several viral and bacterial agents responsible for BRD. There is no single cause for the onset of this disease as it is a multifaceted problem. Because of the complexity of the disease, it requires more than a one dimensional approach to combat it.

Some of the most common bacterial species associated with BRD are *Pasteurella* (*Mannheimia*) *haemolytica, Pasteurella multocida*, and *Histophilus somni* (Duff and Galyean, 2007). The viral agents include parinfluenza-3 (PI3), bovine respiratory

syncytial virus (BRSV), infectious bovine rhinotraceitis (IBR), bovine viral diarrhea virus (BVDV), and bovine enteric coronavirus (Fraser, 1991; Plummer et al., 2004).

Nyamusika et al. (1994) explained that a susceptible animal is non-infected and capable of developing the disease. During the infectious period, the infected animal spreads bacteria or viruses to the susceptible animals. Infectivity often ends when the first clinical signs of the disease appear.

Animals affected with BRD may express varying degrees of symptoms. These include nasal or ocular discharge, depression, lethargy, emaciated body condition and labored breathing (Duff and Galyean, 2007). In a study by Wildman et al. (2008), animals diagnosed with BRD were described as showing evidence of depression. This was characterized by lack of response to stimulation, reluctance to move, and/or abnormal posture/carriage of the head.

Economic Impact

Not only is BRD the most common feedlot disease, it is the most economically important (Galyean et al., 1999; Schneider et al., 2009; Snowder et al., 2007). There are a number of costs associated with BRD beginning in the early phases of diagnosis and ending at harvest of finished cattle. The detrimental affects of BRD can be seen through every stage of feedlot production; however it is most notable in the beginning of the receiving period.

As stated in a review by Smith (1998), "…morbidity of cattle may cost even more than mortality considering the expenses associated with medications, labor involved with

treatment, premature culling because of chronic conditions, and the expense of reduced performance during and after an illness." In addition, losses are seen in decreased performance of affected animals through decreased ADG and decreased percentage of cattle grading choice (Sanderson et al., 2008). Griffin (1997) estimated that the cost of BRD from weaning to packers to be approximately 7% of the total production cost when compared to healthy animals. Schneider et al. (2009) analyzed data from 5,976 cattle from 10 different feedlots. They reported an incidence rate of 8.17% with a total of 105 mortalities, 49% due to BRD. A total of 488 animals were treated for BRD with 53% treated once, 34% treated twice, and 13% receiving three or more treatments. Overall ADG and final BW differed between treated and untreated cattle (Schneider et al., 2009). In the first 4-6 weeks on feed, treated cattle exhibited a reduction in ADG. Schneider et al.(2009) concluded that this indicates cattle suffer the greatest losses in performance during the early feeding period with apparent compensatory gain being observed in treated cattle. Treated cattle had less desirable estimates for all carcass traits compared to cattle not treated. Reductions were reported in HCW (hot carcass weight) (8.16 ± 1.38 kg), LM (longissimus muscle) area (0.58 ± 0.32 sq cm), BF (back fat) (0.76 ± 0.25 mm), and marbling score (0.13 ± 0.04) (Schneider et al., 2009). Schneider et al. (2009) also reported that as the number of treatments increased performance decreased. Cattle that did not receive treatment were at least $23.00 more valuable than treated cattle (Schneider et al., 2009).

In the Texas A&M Ranch-to-Rail program, over a four-year period, healthy steers had an average of $93.20 more favorable return (McNeill, 1999). McNeill (1999) reported that the cost of gain for healthy steers was 14% less than sick steers. Medicine costs for sick animals averaged $31.97 and 26% of all cattle received treatment for respiratory disease (McNeill, 1999).

Gardner et al. (1999) reported that steers diagnosed with BRD in the finishing phase had lower ADG than untreated steers. Treated steers averaged 9 kg less weight gain over the finishing period and had lighter carcass weights. Although Schneider et al. (2009) reported compensatory gain in cattle treated early, Gardner et al. (1999) determined that cattle recovering from BRD never compensated for performance loss during their period of morbidity. Carcasses from untreated steers had more external and internal fat and tended to have greater LM area (Gardner et al., 1999). Additionally, Gardner et al.(1999) reported that steers not treated during the finishing period had higher USDA yield grades compared with treated steers. These findings support conclusions from the Texas A&M Ranch-to-Rail program that cattle affected with BRD gain less, have poorer feed efficiencies, and grade lower than sick cattle (McNeill et al., 1995).

Summary

Bovine Respiratory Disease continues to be the most important feedlot disease in the U.S. because of the number of cattle affected and the negative economic impact that results. Bovine Respiratory Disease accounts for 70% to 80% of total morbidity and 40% to 50% of total mortality (Smith, 1998). The estimated annual loss over 10 years ago was

nearly $1 billion and $3 billion were spent annually for preventative and treatment costs (Griffin, 1997). It is obvious that the beef cattle industry could save millions of dollars if BRD could be reduced or prevented. Research is being conducted to reduce the incidence of BRD, but complete prevention is unlikely.

Health Identification

Introduction

Identifying and treating animals at the first sign of BRD can reduce negative affects on performance and carcass characteristics. There have been various methods developed to aid in identifying sick animals. The most traditional and commonly used method is visual observation. Many other methods of blood and breath analysis and temperature measurements have been used in attempts to verify incidences of BRD. Post-harvest, the appearance of lung lesions is commonly used to confirm BRD infection or identify those animals that may not have shown visible signs of infection.

Feed and Water Intake

When an animal is sick, there will be notable changes in feed and water intake patterns, especially in newly received cattle. Sowell et al. (1998) used radio frequency technology to collect information on feeding patterns of 108 steers for the first 32 days after entering the feedlot. Sowell et al. (1998) reported that healthy steers spent 30% more time at the feed bunk than morbid steers and that differences were most evident in the first four days. At feed delivery time, the presence of healthy steers was 13% greater than morbid steers. The percentage of healthy animals that visited the feed bunk in the

first 15 minutes of feed delivery was greater than for morbid steers indicating that using the first several minutes following feed delivery to identify sick animals could be beneficial (Sowell et al., 1998). In typical feedlot situations it is impossible to measure individual animal DMI; however, intake and weight gains are related and calves treated for BRD have decreased ADG compared to those of untreated calves (Gardner et al., 1999; Montgomery et al., 2009; Schneider et al., 2009).

Basarab et al. (1997) automatically monitored watering behavior of feedlot steers as an early indicator of respiratory disease. Steers treated for respiratory disease had a 23.7% reduction in watering behavior compared to steers not treated for sickness. This method accurately identified sick animals over 80% of the time. Basarab et al. (1997) concluded that automated electronic monitoring of watering behavior could aid in early detection of respiratory disease.

Detection Methods

Cattle are typically observed daily by trained personnel and assessed for signs of BRD. One commonly used system for categorizing the level of health in calves is the DART System (Pharmacia Upjohn Animal Health, Kalamazoo, MI). Step et al. (2008) presented some modifications to the DART System where they expanded upon the basic criteria for depression, abnormal appetite, and respiratory signs. Signs of depression were depressed attitude, hanging head, sunken or glazed eyes, slow movement, arched back, difficulty getting up, dragging toes while walking, and stumbling when moving. Signs of abnormal appetite included being off feed, eating less than expected, slow eating, lack of

fill, and obvious BW loss. Respiratory signs were obvious labored breathing, extended head and neck, and noise when breathing. Severity scores of 1 to 4 were also assigned to suspected sick animals. A score of 1 was assigned for mild, 2 for moderate, 3 for severe, and 4 for moribund (would not rise from recumbency) calves. The final criterion used to determine if treatment was necessary was rectal temperature. If an animal had a rectal temperature of 40.0°C or greater antibiotics were administered. In previous studies, rectal temperatures of 39.7°C, 40.0°C, and 40.5°C have been used as an objective determinant for antibiotic treatment (Galyean et al., 1999; Morck et al., 1993; Wildman et al., 2008). Perino and Apley (1998) also used a clinical scoring system ranging from 0 to 4 similar to that of Step et al. (2008).

Laboratory tests for BRD causative bacteria and viruses have been used in previous research. It should be noted that the value of a laboratory procedure is limited by the time it takes to complete. Tests that are available at the chute would be very valuable but when considering the cost and insufficient data to support their efficacy, they are not widely used.

Plasma metabolites such as glucose, lactate, and urea N concentrations have been measured as an indicator of stress in cattle. However, there is contrasting evidence as to how concentrations of these metabolites change. Galyean et al. (1981) reported an increase of serum glucose in mature cattle that were fasted and transported for 28 h compared to those that were fasted and not transported. Urea N concentrations were lower in both fasted and transported and fasted cattle compared to control cattle (Galyean

et al., 1981). A study conducted by Montgomery et al. (2009) measured plasma glucose, lactate, urea N concentrations, and rectal temperature at initial processing of 665 heifers. Plasma glucose concentrations decreased linearly for heifers never treated for BRD and those that were treated once, twice, or three times (Montgomery et al., 2009). Plasma lactate concentrations also decreased linearly for heifers treated for BRD. Montgomery et al. (2009) reported that plasma urea N concentrations were greater for heifers treated for BRD than not treated. At time of initial processing, rectal temperature tended to be higher for heifers treated for BRD compared with those not treated for BRD (Montgomery et al., 2009).

Acute-phase proteins have been measured in cattle with BRD, including fibrinogen, haptoglobin, and ceruloplasmin (Arthington et al., 2008; Carter et al., 2002; Step et al., 2008). Arthington et al. (2008) compared acute-phase proteins of calves from four different weaning management strategies as previously described. Arthington et al. (2008) found that haptoglobin concentrations increased 160% across all treatments after calves traveled approximately 1,600 km with levels returning to normal eight days later. Creep-fed calves tended to have a greater increase in plasma haptoglobin compared with preweaned calves. Early-weaned and control calves had similar increases in plasma haptoglobin concentrations from d 0 to 1 (Arthington et al., 2008). Initial ceruloplasmin concentrations were less in control steers compared with early-weaned steers. However, after transport, ceruloplasmin concentrations increased dramatically in both groups and were greater in control steers compared with early-weaned steers on d 15 and 22.

Ceruloplasmin concentrations tended to be greater in creep-fed calves compared with preweaned calves (Arthington et al., 2008).

Post-slaughter confirmation of BRD in individual animals can be done through the identification of lesions in the respiratory tract. Gardner et al. (1999) reported that 50% of steers were treated for respiratory disease at least once during the finishing period. Of those that were diagnosed with respiratory infection, 48% had lung lesions and 14% of those had active bronchial lymph nodes. However, 37% of steers never diagnosed as being sick during the finishing period had respiratory tract lesions, of which 9% had active bronchial lymph nodes. Gardner et al. (1999) outlined three reasons as to why there was a high incidence of respiratory tract lesions in steers never diagnosed with BRD: 1) lung damage occurred during an asymptomatic respiratory infection; 2) BRD occurred prior to finishing phase; or 3) respiratory infection resulted from a viral rather than bacterial infection. Gardner et al. (1999) also gave four reasons as to why 52% of cattle treated for BRD had no appearance of lesions: 1) detection of subclinical infection; 2) imprecise clinical diagnosis; 3) full recovery from respiratory infection; or 4) fever detected was in reaction to a viral challenge but the animal did not experience clinical disease. Steers without respiratory tract lesions had the heaviest final live weights with an 11% greater daily weight gain compared with steers that had lesions (Gardner et al., 1999). Steers with active bronchial lymph nodes had 18% lower ADG than steers with inactive bronchial lymph nodes. Based on these results, Gardner et al. (1999) concluded

that cattle that had suffered from BRD never compensated for the performance lost while they were sick.

Limitations of Current Technologies

Each of the detection methods mentioned are useful; however, they do not lack fault. The subjectivity of visual observation leads to inaccuracy and inconsistency of identifying sick animals. A variety of laboratory tests have been used, yet Duff and Galyean (2007) stated, "…the optimal metabolite, compound, or organism to measure remains to be determined." The use of lung lesion data is helpful when determining the effectiveness of other identification methods, but this information is not available until the animal has been harvested. However, it has been shown that performance traits are correlated more closely with respiratory tract lesions at harvest than with evaluation by clinical appraisal (Gardner et al., 1999).

Once cattle are identified as being sick, the final determinant for antibiotic treatment in many systems is based on rectal temperature. When animals are being moved from their pens to a processing facility, there is the potential for body temperature to increase due to movement, crowding, and a variety of other factors (Galyean et al., 1995). The effects of physical activity on body temperature are important if temperature is used as an indicator of health status. Therefore, care should be taken when interpreting rectal temperature readings so that medication is not administered to animals that are not experiencing a fever due to disease related conditions. Mader et al. (2005) reported that moving cattle 150 m or more increased tympanic temperature and recovery times ranged

from <1 h to 3.5 h depending on the season. It was concluded that effects of cattle movement on body temperature need to be considered when evaluating animal health status (Mader et al., 2005).

Summary

The process of identifying and treating sick animals needs to be improved. There is great potential for other methods to emerge that are cost effective, accurate, and consistent. While one point in time temperatures measured after induction of stress have significant limitations, temperature measures that can be collected regularly without inducing stress offers a potential to measure a response that may help in the detection of BRD infected animals. The earlier an animal can be detected, the greater the likelihood of recovery from respiratory disease and the fewer chances of decreased performance and carcass quality.

Methods of Temperature Monitoring

Introduction

Core body temperature can be measured in the ear canal, peritoneal cavity, rumen, and most commonly the rectum. The normal range of core body temperature for cattle is 38.0 to 39.5°C (Davis et al., 2003a). Core body temperature in cattle exhibits diurnal variation due to normal animal activity and ambient temperature. To get valid temperature measurements, it is important to insure that body temperatures are not influenced by induced movement or stress. In unrestrained animals, measurements can be taken through telemetry systems in which data are transmitted via radio transmitters to a

receiver connected to a datalogger or by small battery-powered dataloggers that store data in an on-animal memory unit.

Rectal probes

A study by Brown-Brandl (2003) investigated core body temperature response to thermoneutral conditions and heat challenges. Nine steers were housed in environmental chambers. Rectal temperature was measured with a stainless steel probe inserted to a depth of approximately 20 cm and recorded data every minute. Steers were exposed to three treatments of 18°C, 30°C, and 34°C that lasted 11 days each. Rectal temperature increased significantly as ambient temperature increased (38.90°C, 39.46°C, and 40.11°C). Rectal temperature was affected by treatment, time of day, and treatment x time of day.

Reuter et al. (2007) used rectal probes to detect increases in temperature following a LPS challenge. The automatic thermometer devices were attached to the tail by Velcro straps and placed in the rectum. An increase in temperature from about 38.8 to 41.5°C was detected, peaking at four hours post challenge. The steer did not reach basal temperature levels below 39°C until eight hours post challenge (Reuter et al., 2007). Difficulties with this method developed as some data was lost due to the probe coming out of the rectum. Measuring body temperature by means of a rectal probe is beneficial, but current methods of measurement are viable for single or short term continuous measurements.

Tympanic Membrane Recorders

Tympanic temperature is measured by noninvasive sensors secured in the ear canal. Mader et al. (2005) measured tympanic temperature in feedlot steers using thermistor cables that were placed into the ear canal, near the tympanic membrane, at a depth of approximately 12 cm. The thermistors were connected to data loggers that were secured to the outside of the ear. In the winter, tympanic temperature increased 0.65°C when cattle were moved 600 m in the morning and 0.58°C when moved in the afternoon. In the summer, moving cattle 150 and 600 m increased tympanic temperature by 0.30°C and 0.67°C, respectively. It took an average of 3.5 hours in the winter for increased body temperatures to return to normal and less than 3.5 hours for spring and summer months. Tympanic membrane recorders are conveniently located on the animal since the location is not economically important. However, animals with tympanic membrane recorders should be monitored closely for infection at insertion site and should not be used for extended periods of time (Davis et al., 2003a).

Implanted Transmitter

Several researchers have evaluated the usefulness of implanted telemetry transmitters to determine effects low and high ambient temperatures and calving on core body temperature (Davis et al., 2003a; Lammoglia et al., 1997; Lefcourt and Adams, 1996b). The transmitters are encased in a cylinder and surgically placed near the ribcage inside the peritoneal cavity.

Lefcourt and Adams (1996b) monitored core body temperatures of 10 feedlot steers for almost 170 d from June to November; however, only 94 d of usable data were recovered. They reported that daily maximum body temperature increased as maximum ambient temperature increased when ambient temperature reached 25.6°C. In the late evening, sharp peaks in body temperature were evident after ambient temperature had decreased well below maximum values. Concerns of using implanted transmitters include the need for surgical implantation, potential of migration, and recovery at harvest.

Davis et al. (2003a) compared temperature measurements over the course of 6 to 9 days at three sites: the rectum, near the tympanic membrane, and peritoneal cavity. During a 24-hour period, the average tympanic and peritoneal temperatures were slightly less than rectal temperature. However, the highest correlation was observed between rectal and tympanic temperatures (Davis et al., 2003a).

Rumen Boluses

Rumen boluses have been used as a carrier for the long and slow release of supplements. Boluses can also be used as a carrier of transponders for electronic identification in ruminants which has laid the foundation for monitoring core body temperature in the reticulo-rumen. Boluses are administered by a balling gun and can be safely retrieved at slaughter and show no signs of irritation to the epithelium of the reticulo-rumen wall (Caja et al., 1999).

Ghiradi et al. (2006), evaluated a number of bolus dimensions and specific gravities and reported that retention rate of at least 99.5% can be achieved with proper

bolus length, minimum weight, and volume. They reported that no boluses of specific gravity lower than 3.0 and diameter of more than 20 mm o.d. should be used for identification of cattle.

Prendiville et al. (2002) conducted a study to compare rumen boluses, tympanic loggers, and rectal temperature readings over a five day period. The average bolus, tympanic, and rectal temperatures over five days were 39.0, 38.4 and 38.2°C, respectively. For three of the five days, bolus temperature measurements were higher than tympanic or rectal temperatures. The overall correlation coefficients for bolus and rectal temperature was 0.34 and for bolus and tympanic was 0.65. However, interactions were noted between methods over time which indicated limitations in each method. Rumen boluses transmitted body temperatures from every animal each hour of every day, up to a distance of one km. It was concluded that the use of rumen boluses can effectively measure body temperature but the efficiency of the bolus needed improvement.

Dye and Richards (2008) successfully demonstrated that remote monitored rumen temperature boluses detected changes in rumen temperature during drinking water events. Rumen temperature boluses administered to four steers were programmed to transmit readings to a remote data station every minute. Data was collected and analyzed for a 72 h period. The parameters evaluated for water drinking occurrences were: length of time spent drinking water, period of time rumen temperature was below normal, rumen temperature time below 37.8°C, length of time to lowest rumen temperature, rumen temperature change, and volume of water consumed. Average rumen temperature was

38.5°C. Water volume consumption that resulted in a change in rumen temperature averaged 2.85 L but was as little as 0.83 L. The average rumen temperature decrease caused by a water event was 1.9°C. The average water volume consumed that did not result in a rumen temperature change was 0.25 L but was as great as 1.02 L. The average time rumen temperature was below 37.8°C was 11.4 minutes. Dye and Richards (2008) concluded that change in rumen temperature is an indicator of the frequency and volume of water consumed (over 1 L) by a feedlot steer. Remote monitored rumen temperature boluses are capable of detecting rumen temperature changes during water drinking events and determining the time below normal rumen temperature. There is a potential to predict volume of water consumed and it could be a tool for assessing water consumption of feedlot cattle and to determine if morbid animals have different watering behavior than their healthy contemporaries.

Summary

Measuring body temperature can be done through a variety of methods. Many of these methods are emerging technologies and the question becomes which one is the most accurate, convenient, practical, sustainable, and economical. The use of rectal probes are a possible alternative to traditional rectal thermometers because thermometers are labor intensive, they only have the capacity to measure one animal at a time, and they require additional handling of the animal. Rectal probes have the ability to measure change in temperature over time by taking continuous measurements. However, rectal probes must be attached to the animal in a way that is not practical for large-scale use.

This technology also needs further developed as it has the tendency to come out of the rectum and lose data.

Tympanic temperature has been found to be a reliable measure of heat stress in feedlot cattle with measurements very similar to rectal temperatures (Davis et al., 2003b; Mader et al., 2002). Administration of these devices requires somewhat skilled training. A thermistor is attached to a datalogger and then inserted several cm down the ear canal until the tip is located near the tympanic membrane. Temperature measurements can only be taken for a few days before being removed. In previous research this method was only used for small numbers of animals and is not likely practical for use in large-scale operations.

Surgically implanted transmitters can be used for longer durations than rectal probes and tympanic membrane recorders. They record continuously and can be programmed to transmit data in frequent intervals. These transmitters are the most invasive method and in one example required a recorder and datalogger to be attached to the animal through a harness near the shoulder (Davis et al., 2003a). Not only is this method expensive but it involves a great deal of labor to ensure that all components of the system remain intact and in place on the animal. Using this method would not be practical outside of a research setting.

The development of rumen boluses may be the most convenient way for producers to monitor body temperature. The temperature boluses can be administered noninvasively and can remain in the rumen without causing negative side affects to the

animal. They are capable of transmitting data frequently and continuously and can be used in a commercial setting. This makes them capable of monitoring the greatest number of animals at one time compared to other methods. Because they are the able to detect changes in rumen temperature they have potential to detect morbid animals. The rumen is a unique environment that does present challenges. The dynamics of the rumen make it susceptible to temperature change from water intake and type of diet, due to heat of fermentation. These examples could make it difficult to truly see a change in temperature from illness. This method may have the longest duration in the body, offering the most potential amount of data, however it may present some challenges for recovery in commercial harvest facilities.

Conclusion

Respiratory disease is an economical detriment to the beef industry, costing billions of dollars each year in the form of reduced performance, treatment costs, increased mortality, increased morbidity, and less desirable carcasses. The beef cattle industry will continue its attempts to reduce the incidence of BRD, in the meantime, research is being done to equip producers with tools that will detect and treat infected animals more efficiently. The more quickly an animal can be identified as sick, the better chances are for successful treatment, reduced extent of the disease, and reduced economical consequences.

Rumen boluses may be the most promising emerging technology that can continuously and remotely transmit temperature data without inducing stress on the

animal. The industry relies heavily on visual appraisal of animals, leaving plenty of room for human error. Rumen temperature boluses can be used as a tool to assist in the identification of sick animals. The rumen is a dynamic environment that is affected not only by core body temperature, but also heat of fermentation and consumption of water. In the future, rumen boluses may be fitted with additional sensors that may be capable of measuring pH, pressure, and metabolites such as ammonia. There is potential for this technology to be used on a large scale in feedlots, even though more research needs to be conducted to determine temperature characteristics that are strongly associated with early stages of BRD.

CHAPTER III

USE OF RUMEN TEMPERATURE BOLUSES FOR DETECTION OF BOVINE RESPIRATORY DISEASE

Abstract

Heifer calves (241±17kg) were purchased in western Kentucky, comingled, dosed with a remote, continuous monitoring rumen temperature bolus (SmartStock, LLC), and delivered to the Oklahoma State University Willard Sparks Beef Research Center to evaluate the effectiveness of rumen temperature boluses as a health management tool during a 42-d receiving period. One hundred sixty-eight calves were used for observation. After arrival, calves were stratified according to High, Medium, and Low arrival blood haptoglobin concentrations. Calves were evaluated each day by two trained individuals to assess signs of respiratory or other diseases. Each calf was given a visual severity score of: 0) normal, 1) mild, 2) moderate, 3) severe, or 4) morbid based on clinical signs. Any animal scored 1 or higher was transferred to a processing facility (pulled) for further examination. At examination, if rectal temperature was greater than 40°C, the calf was treated according to a predetermined antimicrobial regimen. After the completion of the receiving period, individual calves were classified according to three additional parameters that relate to health status. Calves were classified by one of three 0 to 42-d ADG categories; one of four categories based on health history; by the number of times treated, and data were evaluated by time of day. No differences were detected in 42-d

average rumen temperature across haptoglobin categories ($P = 0.22$). Calves with low 42-d ADG had the greatest ($P < 0.10$) 21 and 42-d average temperature and average maximum temperature, whereas calves with high 0 to 42-d ADG had the lowest ($P < 0.10$) average temperature and average maximum temperature for all three periods. Over 42 d, average and maximum rumen temperature increased ($P < 0.10$) from calves that were never pulled or alarmed (NPNA), to calves that had rumen temperature alarms but were not pulled (NPA), to calves that were pulled and treated (PT). As the number of times calves were treated increased, 7, 21, and 42-d ADG decreased ($P < 0.10$). Rumen temperatures showed evident diurnal variation. The lowest average temperatures occurred in the morning between 0800 and 1200 and the highest average temperatures over 42 d occurred in the late afternoon and early evening between 1600 and 2000. These results indicate potential for using rumen temperature boluses to assist in health management of receiving cattle and as a predictor of animal performance.

Key Words: Cattle, Health, Temperature, Receiving Cattle

Introduction

Preventing, detecting, and effectively treating bovine respiratory disease (BRD) continues to be a prominent issue in the feedlot industry. Not only is BRD the most common feedlot disease, it is the most economically important (Galyean et al., 1999; Schneider et al., 2009; Snowder et al., 2007). There are a number of costs associated with

BRD beginning with treatment costs and carrying to harvest with reduced performance and carcass quality. The detrimental effects of BRD can begin in any stage of feedlot production; however it is most notable within the first 14-21 d of the receiving period. Several avenues to indentify cattle with BRD have been explored. Recently, rumen temperature monitoring has been shown to be an indicator of health status in cattle challenged with a common BRD bacterium (Dye, 2007). The objective of this study was to assess the effectiveness of using remote rumen temperature boluses as a management tool for detecting BRD in high risk cattle.

Materials and Methods

Animals

Two loads of 360 total head of British and British x continental heifer calves (241 ± 17 kg) were purchased and commingled in western Kentucky and then shipped approximately 875 km to the Oklahoma State University Willard Sparks Beef Research Center in Stillwater, Oklahoma. Calves were received two days apart. Day one of the trial for the two groups of calves was September 13 and 15, 2007, respectively and ended on October 24 and 26, 2007, respectively. Prior to being delivered, calves were dosed with a remote monitoring rumen temperature bolus (SmartStock, LLC, Pawnee, OK) using a custom balling gun. Rumen temperatures were monitored during the receiving period. Calves were fed a 45% concentrate dry-rolled corn-based preconditioning diet for the duration of the receiving period.

Blood was collected six hours after arrival. Blood was collected via jugular venipuncture (Clott activator, Becton Dickson Vacuatiner, Franklin Lakes, NJ). After blood sample collection, tubes were allowed to clot for four hours at room temperature before centrifugation and were not stored before analysis was performed. Once all serum samples were collected, a bovine haptoglobin ELISA test (Immunology Consultants Lab, Portland, OR) was used to determine haptoglobin concentration of each serum sample. Prior to analyses, serum samples were diluted 1:1000 in tris buffered saline with tween 20, pH 4.0 (Sigma, St. Louis, MO). The intra and inter assay coefficient of variation were below 5%. Calves were allotted to 12 pens according to arrival haptoglobin concentrations into three groups; Low (< 1 μg/100 mL), Med (1 to 3 μg/100 mL), and High (> 3 μg/100 mL).

Calves were evaluated at the same time each day by two trained individuals to assess calves for signs of respiratory or other diseases. Evaluators used criteria based on the DART system (Pharmacia Upjohn Animal Health, Kalamazoo, MI) with modifications described by Step et al. (2008). The system uses subjective criteria to identify BRD sings in cattle including depression, abnormal appetite, and respiratory signs. Calves were assigned severity scores of 0 to 4, where 0 was assigned for the absence of signs, 1 for mild, 2 for moderate, 3 for severe, and 4 for morbid. Any calf scoring 1 or greater was transferred to the processing facility (pulled) for further examination. At the processing facility, calves were weighed and rectal temperature was determined using a rectal thermometer (GLA M-500; GLA Agricultural Electonics, San

Luis Obispo, CA). Any calves with a DAR score of 1 or 2 and a rectal temperature of 40.0°C or greater received an antimicrobial. Any calves assigned a DAR score of 3 or 4 were administered an antimicrobial regardless of rectal temperature. If the calf did not meet the subjective severity score and temperature criteria, no antimicrobial treatment was administered. All calves were returned to their home pens regardless of treatment. Temperature readings, BW, and antimicrobial treatments were recorded for each calf that was examined for clinical signs of BRD.

Tilmicosin (Micotil 300, Elanco Animal Health, Greenfield, IN) was the first antimicrobial treatment given to calves suffering from clinical BRD at a dosage rate of 10 mg/kg of BW. After 48 h of receiving the first treatment, calves were eligible to receive a second antimicrobial treatment of enrofloxacin (Baytril 100, Bayer Corp, Shawnee Mission, KS) at a dosage rate of 10 mg/kg of BW. If calves required a third antimicrobial treatment, they were eligible to receive ceftiofur HCl (Excenel RTU, Pharmacia Upjohn) at a dosage rate of 2.2 mg/kg of BW 48 h after receiving their second treatment. A second dose of ceftiofur HCl was repeated in 48 h. Any calf that met criteria for a fourth treatment and had lost body weight during the previous 21 d was considered a chronic and removed from experimental pens.

Calves were classified into a series of different categories to compare against average and average maximum rumen temperature measures to evaluate the effectiveness of the rumen temperature bolus to assist in detecting BRD over a 42-d receiving period. Initially, calves were classified by one of three ADG categories based on 0 to 42-d ADG:

1) Low (< 0.68 kg); 2) Medium (0.68 kg to 1.59 kg); and 3) High (> 1.59 kg), calculated for 0 to 7, 0 to 21, and 0 to 42 d. Calves were also classified based on health history into one of four categories: 1) never pulled and no alarm (NPNA); 2) never pulled, but alarmed (NPA); 3) pulled, but not treated (PNT); or 4) pulled and treated (PT). A sustained rumen temperature, or alarm, was acknowledged when calves had a rumen temperature of 40°C or greater for three or more consecutive hours at least once during the receiving period. Additionally, calves were categorized by the number of times treated: 0, 1, 2, or 3 or more times. Data was also evaluated by time of day, resulting in six time blocks; 0001 to 0400, 0401 to 0800, 0801 to 1200, 1201 to 1600, 1601 to 2000, and 2001 to 0000.

Data Collection

Rumen temperatures were transmitted every 30 minutes if rumen temperature was under 40.2°C, every 15 minutes if rumen temperature was 40.2°C or greater, and every 5 minutes if rumen temperature fell below 37.8°C. Data was transmitted wirelessly from the bolus to a receiver. Boluses were estimated to transmit data up to 91 m from the receivers. A total of four receivers were used across the front of ten 12.2 m x 24.4 m pens. Receivers then wirelessly transmitted data to a remote data station in a building near the pens. Temperature data was logged on a personal computer in spreadsheet form. Each transmitted reading was time stamped and identified with a unique number that corresponded to the calves' identification number.

Statistical Analyses

Data were analyzed using the MIXED procedure of SAS (SAS Inst. Inc., Cary, NC). Animal was the experimental unit. In the statistical model independent variables were health categories and animal within pen was used as a random variable. Health categories were haptoglobin concentration, 0 to 42 d ADG, health history, and number of times treated. Dependent variables included 7, 21, and 42-d average temperature and average maximum temperature, total number of times pulled, day of each pull, total number of times treated, day of each treatment, alarm event before each pull, average temperature before each pull and each treatment, serum haptoglobin concentration, and 0 to 7, 0 to 21, and 0 to 42 d ADG. Mean separations were performed for treatments when $P < 0.10$ with the PDIFF procedure. Regression analyses were performed using the CORR procedure of SAS. Haptoglobin concentration was the independent variable and 7, 21, and 42 d average and average maximum temperatures were the dependent variables. Temperatures below 37.8°C were assumed to be related to water drinking events and were removed before analysis. Temperatures that were read in 15 minute intervals were reduced to one reading per 30 minutes before all temperatures were averaged.

Results & Discussion

Of the 360 calves, 168 met the reading frequency requirements and were used for these analyses. The 168 calves reported 153,898 total readings for the 42-d receiving period which averaged 21.8 ± 5.7 readings per animal per day. A number of boluses only performed intermittently or stopped transmitting before the end of the receiving period. If

more than 20% of total transmissions were not recorded during the 42-d receiving period the calf's data was eliminated from the data set.

In general, average rumen temperatures were greatest in the week of arrival and lowered progressively during the receiving period. This is likely not due to effects of ambient temperature but improvement of herd health. Figure 1 compares average ambient temperature and average rumen temperature, showing that ambient temperature did not have an obvious impact on rumen temperatures. Correlation of average ambient temperature and average rumen temperature revealed a relatively moderate R^2 of 0.51. Comparison of minimum ambient temperature vs. minimum rumen temperature was weakly correlated ($R^2 = 0.14$), and maximum ambient temperature vs. maximum rumen temperature was also weakly correlated ($R^2 = 0.13$). Dye (2007) reported an R^2 of 0.53 when comparing ambient maximum daily temperature and average daily maximum rumen temperature in steers housed in covered pens. Additionally, Dye (2007) compared ambient maximum daily temperature and average daily mean rumen temperature resulting in an R^2 of 0.02. As expected, when a calf was treated due to signs of respiratory disease and elevated rectal temperature, rumen temperature decreased shortly after the antimicrobial was administered (Figure 3). Richeson et al. (2009) reported average decreases of 0.67°C in rectal temperatures of calves 48 h after receiving treatment. In this study, rumen temperature 24 h after treatment averaged 39.44 °C, which was a decrease of 1.11°C. Of the calves that received at least one treatment, 95 calves had subsequent increases in rumen temperature an average of 2.8 days later. Of the calves that received

two treatments 46 had elevated rumen temperatures an average of 5.3 days later, and of the calves that received three treatments 28 had elevated rumen temperatures an average of 6 days later. The average day of first, second, and third treatments were 7, 13, and 19 days, respectively. Rectal temperatures at time of treatment averaged 41.02°C.

Haptoglobin. Haptoglobin concentrations on arrival were 0.79, 1.93, and 7.60 μg/100 mL with 49, 28, and 91 calves in the Low, Med, and High categories, respectively. Average and average maximum rumen temperatures were not different among haptoglobin categories at any point during the receiving period (Figures 11, 12, 13). Calves in the Low haptoglobin category received fewer treatments for BRD than calves with greater haptoglobin concentrations (Table 2). Average daily gain did not differ among haptoglobin categories throughout the receiving period. Numerically, calves in the High haptoglobin category had the lowest ADG in the 7 and 42-d periods as would be expected.

Previous researchers reported that as the number of treatments increase, serum haptoglobin concentrations also increase (Berry et al., 2004; Carter et al., 2002), but no comparisons to body temperature have been made. Haptoglobin level and average rumen temperature were weakly correlated ($r = 0.10$). Average rumen temperature 24 h prior to first treatment averaged 39.95°C ± 0.41 across all haptoglobin categories, with the first treatment occurring in the first seven days upon arrival (Table 2). In this study, haptoglobin concentrations do not appear to be a clear health predictor over the 42-d receiving period. The reported serum haptoglobin concentrations are much lower than

what has been described in previous studies. Carter et al. (2002) observed haptoglobin concentrations in heifer calves as great as 400 μg/mL on day 0 and greater than 500 μg/mL on day 7. Similarly, Berry et al. (2004) reported haptogloblin concentrations in bull and steer calves over 700 μg/mL on day 0 and over 900 μg/mL on day 7. Therefore, initial haptoglobin concentrations of heifer calves in this study may not have been high enough to detect differences in health or performance. Also, it is important to realize that the data analyzed from the 168 calves is a subset of a larger group of calves.

ADG. Average daily gain for calves in the Low, Medium, and High ADG categories were 0.30, 1.18, and 1.84 ± 0.06 kg, respectively (Table 1). Except for the number of times pulled in the first 7 days, the 7, 21, and 42 d ADG, times pulled, and times treated for the Low ADG category were different from the Medium and High ADG categories. Except for the number of times pulled and treated in the first 7 days, the 7, 21 and 42 d ADG, times pulled and times treated were different for the Medium and High categories. Over 42 d, calves in the Low category were pulled an average of 3.12 ± 0.19 times and treated an average of 2.66 ± 0.21 times, which was higher than the Medium and High categories ($P < 0.10$; Table 1). This is in agreement with Montgomery et al. (2009), who reported that calves receiving three treatments for BRD also had the lowest ADG during the receiving period compared with calves receiving fewer treatments. For the 7, 21 and 42 day period, average rumen temperature decreased as ADG category increased (Figures 4, 5, and 6). The average maximum temperature was lowest in all three time periods for the High ADG category, and Medium ADG category had lower

maximum temperatures than the Low ADG in the 21 and 42 d periods. Average rumen temperatures and average maximum rumen temperatures for the 7, 21, and 42 d periods are presented in Figures 4, 5, and 6. The 7-day average temperature decreased with increasing ADG category while there was no difference in the Low and Medium maximum temperature. The 21 and 42-d average and average maximum temperatures decreased with increasing ADG category.

The present experiment supports data stating that morbid calves will typically perform more poorly than healthy calves, due to less time spent at the feed bunk, stress of transportation, change of diet, or from handling that is required for medical treatment (Buhman et al., 2000; Montgomery et al., 2009). According to Gardner et al. (1999), steers diagnosed as sick had lower ADG than those that were not sick, gaining 9 kg less than healthy steers during the 150-d trial. Buhman et al. (2000) reported similar findings that sick calves performed nearly a half kg poorer than calves that were not sick. Additionally, Cusack et al. (2007) reported that BRD had marked effects on ADG in feedlot calves, decreasing gains by 0.70 kg/d. The above experiments indicate that sick calves have reduced gains and therefore decreased ADG may be an indicator of illness. Overall ADG vs. 42-d average rumen temperature resulted in a relatively weak correlation (R^2 = -0.39). However, in this experiment, slow gaining calves had higher average rumen temperatures and average maximum rumen temperatures meaning that elevated rumen temperatures may be an indicator of health status in feedlot cattle.

Pulled/Treated Categories. Over the 42-d receiving period 5, 34, 8, and 121, calves were classified in the NPNA, NPA, PNT, and PT categories, respectively. Over the first 7 days, NPNA calves had a lower average rumen temperature than NPA or PT calves (Figure 7). The PNT calves' average temperature was lower than the PT calves while the NPA calves were intermediate and not different from the PNT or PT calves. For 7-d average maximum temperature, NPNA and PNT calves were lower than NPA and PT calves. For the 21-d average temperatures, NPNA calves had lower average temperatures than NPA or PT calves (Figure 8). The NPA and PNT calves' average temperatures were not different, but were lower than PT calves. For 21-d average maximum temperatures, NPNA and PNT calves were lowest, NPA calves were intermediate, and PT calves were the highest. Over 42 d, average and maximum rumen temperature increased from NPNA to PNT to NPA to PT calves (Figure 9). For average rumen temperature, PNT calves were not different from any average temperatures of the remaining treatments, while PNT calves' average maximum temperature was not different from NPA and NP calves. While final numbers are low for NPNA and PNT calves, these two categories along with NPA calves represent calves that were never treated. The low number of PNT calves in this study suggests that, in this experiment based on total number of pulls and total number of treatments with 72% of calves receiving treatment, visual identification was 93.7% successful in identifying calves that received a treatment during the experiment. NPA calves were not visually identified for treatment and were not treated; however, their temperatures were higher than NPNA calves and at least numerically intermediate

between PNT and PT calves which indicate that at least a portion of the NPA calves were experiencing health challenges not detected through visual observation. This could indicate that calves that are pulled for treatment experience elevated body temperatures in addition to the fever that they already have as a result of moving and handling, particularly within the first several days after arrival. Mader et al. (2005) reported that moving cattle 150 m or more increased tympanic temperature and recovery times ranged from less than1 h to 3.5 h depending on the season. It was concluded that effects of cattle movement on body temperature need to be considered when evaluating animal health status (Mader et al., 2005). It should also be noted that the temperature alarm parameters may have mistakenly identified a portion of healthy calves and may need to be modified in subsequent research.

Average daily gain for the first seven days was greatest for NPNA and NPA calves while PNT calves had the lowest (Figure 10). Pulled and treated calves had the lowest 21 and 42 d ADG which was 0.48 kg/d lower than the average of the other three treatments which did not differ. The increased temperature for NPA calves without decreased gains could indicate that calves detected by rumen temperature alarms were not experiencing the severity of disease as treated calves and were able to prevent the heath challenge from requiring treatment. It is also possible that the protocol for determining sickness for the NPA calves was selecting a combination of healthy and sick calves. Schneider et al. (2009) reported that animals treated for BRD had a reduction of 0.37 ± 0.03 kg/d during the acclimation period and a reduction of 0.07 ± 0.01 kg/d for overall

ADG. Based on these results they concluded that cattle suffer the greatest loss in performance during the early feeding period and some amount of subsequent compensatory gain is evident in treated cattle (Schneider et al., 2009).

Number of times treated. Over 42 d, 47 calves never received treatment, 56 were treated once, 22 were treated twice, and 43 were treated three or more times which results in an overall morbidity of 72% for calves with functioning boluses. A comparison of 42-d average rumen temperature and the number of times treated resulted in a moderately weak correlation ($R^2 = 0.33$). Calves treated three or more times had the greatest 7, 21, and 42-d average rumen temperatures and average maximum rumen temperatures (Figures 14, 15, and 16). However, there were no significant differences in average temperature among calves that never received treatment and calves that received less than three treatments. Only the 21-d average maximum temperatures were increased in calves over those receiving no treatments. In the first seven days on feed, calves that were ultimately treated three times or more during the receiving period maintained an average rumen temperature of 40.00 ± 0.12°C. Rumen temperature boluses were able to detect elevated temperatures in the first week that were likely due to results of stress typically seen in newly received feedlot cattle.

Rumen temperatures were elevated to meet the alarm protocol an average of nearly 21 hours before calves were identified as morbid the first two times they were pulled (Table 3). Calves were clinically evaluated by 0800 every day; therefore, the rumen temperature bolus would be able to identify a sick calf by 1300 on the day before

it was pulled. On average, rumen temperatures averaged 40.02 ± 0.32°C for all calves 24 hours prior to the first treatment and 39.74 ± 0.26°C 24 hours prior to the second treatment. Rumen temperatures were elevated by 0.14°C 24 hours prior to treatment compared to 42-d average rumen temperature for all calves receiving treatment. Compared to calves that did not receive treatment, rumen temperatures were elevated by 0.81°C 24 hours prior to treatment. Rectal temperature at the time of first treatment and second treatment was weakly correlated with 42-d average rumen temperature ($R^2 = 0.11$ and $R^2 = 0.20$, respectively).

In general, as the number of treatments increased, ADG at least numerically decreased over the 7, 21 and 42 day periods. The 42 d results indicates that calves not treated or treated one time had the greatest ADG, treated two times were intermediate, and those treated 3 or more times had the lowest ADG. Schneider et al. (2009) compiled data from several different feedlots over the course of three years. They reported that treated vs. untreated cattle as well as the number of treatments resulted in significant differences for acclimation ADG with ADG decreasing as the number of treatments increased. Montgomery et al. (2009) described the effects of treatments on ADG, stating that heifers treated 1, 2, or 3 times for apparent BRD gained 0.08, 0.35, or 0.58 kg/d less, respectively, than heifers that did not receive treatment. In this experiment, calves treated 1, 2, or 3 times gained 0.12, 0.52, and 0.97 kg/d less, respectively, than calves never treated.

Time of day. Rumen temperatures showed evident diurnal variation with the lowest average temperature occurring in the morning between 0800 and 1200 and the highest average temperature over 42 d occurring in the late afternoon and early evening between 1600 and 2000 (Figures 18, 19, 20). The lowest average maximum temperatures in the 7, 21 and 42 d periods occurred in the morning between 0401 and 0800 and the highest average temperatures occurred between 1201 and 2000. Davis et al. (2003b), reported similar findings for daily tympanic temperatures of steers during severe heat stress conditions. The lowest temperatures occurred between 0600 and 1100 and the highest temperatures occurred between 1600 and 2100 (Davis et al., 2003b). Additionally, Lefcourt and Adams (1996a) reported that core body temperatures of steers in the winter months were lowest in the morning near 0600, and continued to rise until a peak was reached near 1900. The difference throughout the day represents an approximately 0.5°C variation. In context with the 0.14 and 0.81°C elevations in average temperature 24 hours prior to treatment in relation to the 42-d average temperatures, it appears that adjustments for time of day will probably be required

Implications

Results of this study revealed that calves receiving antimicrobial treatment and that have low ADG are likely to have elevated rumen temperatures compared to healthy calves. The feedlot industry relies on visual observation to identify morbid cattle and is verified objectively using rectal temperature measurements. Rumen temperature measurements may be more valuable over rectal temperature because they can be

obtained without handing the animal and could potentially result in detection before visual symptoms surface. Using a remote rumen temperature bolus technology could aid in detecting sick cattle more quickly, allowing for cattle to be treated sooner and possibly prevent the spread of BRD. Early detection may also decrease the negative impacts observed in performance and economic losses attributed to BRD.

Table 1. Number of times calves were pulled and treated based on ADG category during a 42-d receiving period.

	ADG Category[1]				
Item	Low	Med	High	SEM	P-value
n	44	83	41		
0-7 ADG	0.46 [a]	1.40 [b]	2.52 [c]	0.36	<0.0001
No. of times pulled in 7 d	0.77 [a]	0.60 [b]	0.51 [b]	0.14	0.1769
No. of times treated in 7 d	0.68 [a]	0.46 [ab]	0.34 [b]	0.12	0.0120
0-21 ADG	-0.20 [a]	1.01 [b]	2.03 [c]	0.09	<0.0001
No. of times pulled in 21 d	2.32 [a]	1.13 [b]	0.68 [c]	0.22	<0.0001
No. of times treated in 21 d	2.14 [a]	0.98 [b]	0.46 [c]	0.18	<0.0001
0-42 ADG	0.30 [a]	1.18 [b]	1.84 [c]	0.06	<0.0001
No. of times pulled in 42 d	3.12 [a]	1.42 [b]	0.77 [c]	0.19	<0.0001
No. of times treated in 42 d	2.66 [a]	1.18 [b]	0.49 [c]	0.21	<0.0001

[1]Low (< 0.68 kg), Medium (0.68 kg to 1.59 kg), and High (> 1.59 kg); 42-d ADG.
[abc]Means within row with different superscripts differ ($P < 0.10$).

Table 2. Effect of calf haptoglobin category on number of times treated, ADG, and other characteristics during a 42-d receiving period.

	Haptoglobin Category[1]				
Item	Low	Med	High	SEM	P-value
n	49	28	91		
No of times treated	1.00 [a]	1.75 [b]	1.49 [b]	0.28	0.0142
ADG 0-7, kg	1.60	1.64	1.28	0.46	0.6281
ADG 0-21, kg	0.95	0.75	1.01	0.32	0.6905
ADG 0-42, kg	1.20	1.23	1.14	0.23	0.9026
Alarm before 1st pull, h	14.58	25.48	18.93	4.97	0.2681
Alarm before 2nd pull, h	14.50	21.32	23.43	4.48	0.2389
Alarm before 3rd pull, h	6.88	14.23	15.04	4.62	0.3072
Day of 1st Treatment	6.90	7.78	6.14	1.68	0.5095
Day of 2nd Treatment	15.29 [a]	16.27 [a]	11.50 [b]	2.39	0.0315
Day of 3rd Treatment	19.23	19.40	17.93	4.70	0.8999
Temperature 24 h prior to 1st treatment, °C	39.69	40.05	40.12	0.41	0.4628
Temperature 24 h prior to 2nd treatment, °C	39.56	39.29	39.99	0.34	0.1620
Temperature 24 h prior to 3rd treatment, °C	--	39.90	39.83	0.39	0.8715

[1]Low (< 1 μg/100 mL); Medium (1 to 3 μg/100 mL); and High (> 3 μg/100 mL).
[abc]Means within row with different superscripts differ ($P < 0.10$).

Table 3. Effect of number of times treated on ADG and other characteristics for feedlot calves during a 42-d receiving period.

	No. of times treated					
Item	0	1	2	3	SEM	P-value
n	47	56	22	43		
ADG 0-7, kg	2.05[a]	1.74[ab]	1.06[bc]	0.59[c]	0.44	0.0004
ADG 0-21, kg	1.67[a]	1.26[b]	0.68[c]	-0.02[d]	0.20	< 0.0001
ADG 0-42, kg	1.50[a]	1.38[a]	0.98[b]	0.53[c]	0.10	< 0.0001
No. of times pulled	0.17[a]	1.32[b]	2.41[c]	3.51[a]	0.14	< 0.0001
Alarm before 1st pull, h	3.50	19.87	19.36	23.35	7.24	0.0993
Alarm before 2nd pull, h	--	21.80	18.75	22.02	4.97	0.7828
Alarm before 3rd pull, h	--	36.00	6.25	13.50	12.78	0.1246
Temperature 24 h prior to 1st treatment, °C	--	39.86	39.93	40.26	0.32	0.3149
Temperature 24 h prior to 2nd treatment, °C	--	--	39.57	39.90	0.26	0.2258
Temperature 24 h prior to 3rd treatment, °C	--	--	--	39.85	0.18	--

[abc]Means within row with different superscripts differ ($P < 0.10$).

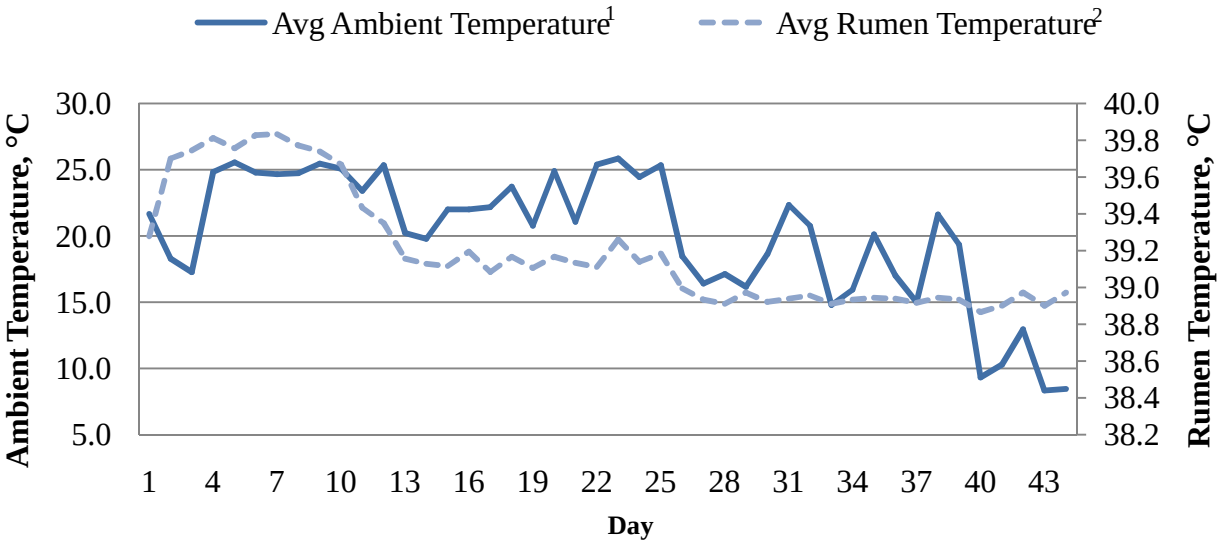

Figure 1. Comparison of average ambient temperature and average rumen temperature of feedlot calves over a 42-d receiving period.
n = 168
[1]Std. dev. = 4.9°C
[2]Std. dev. = 0.3°C

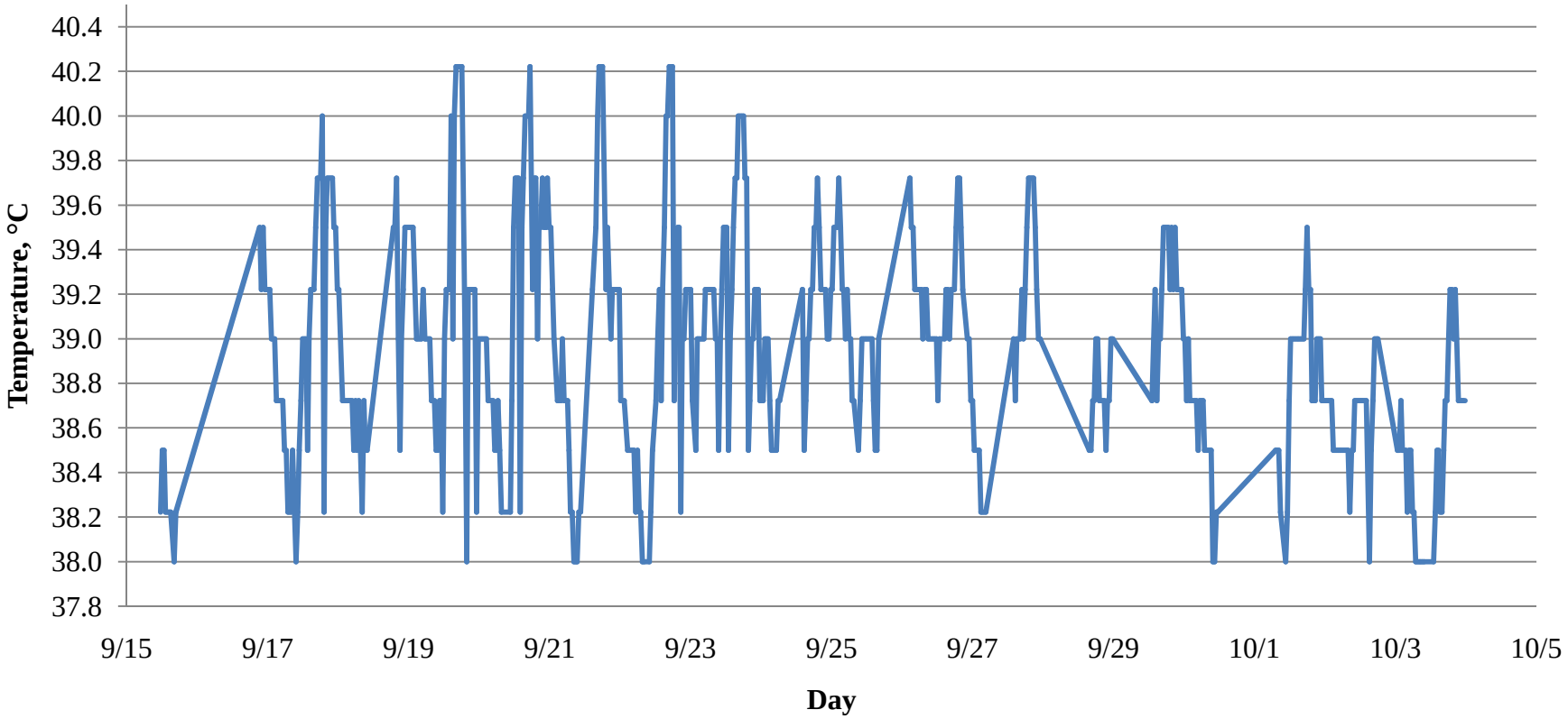

Figure 2. Rumen temperature over 21 d of a calf that never received treatment.

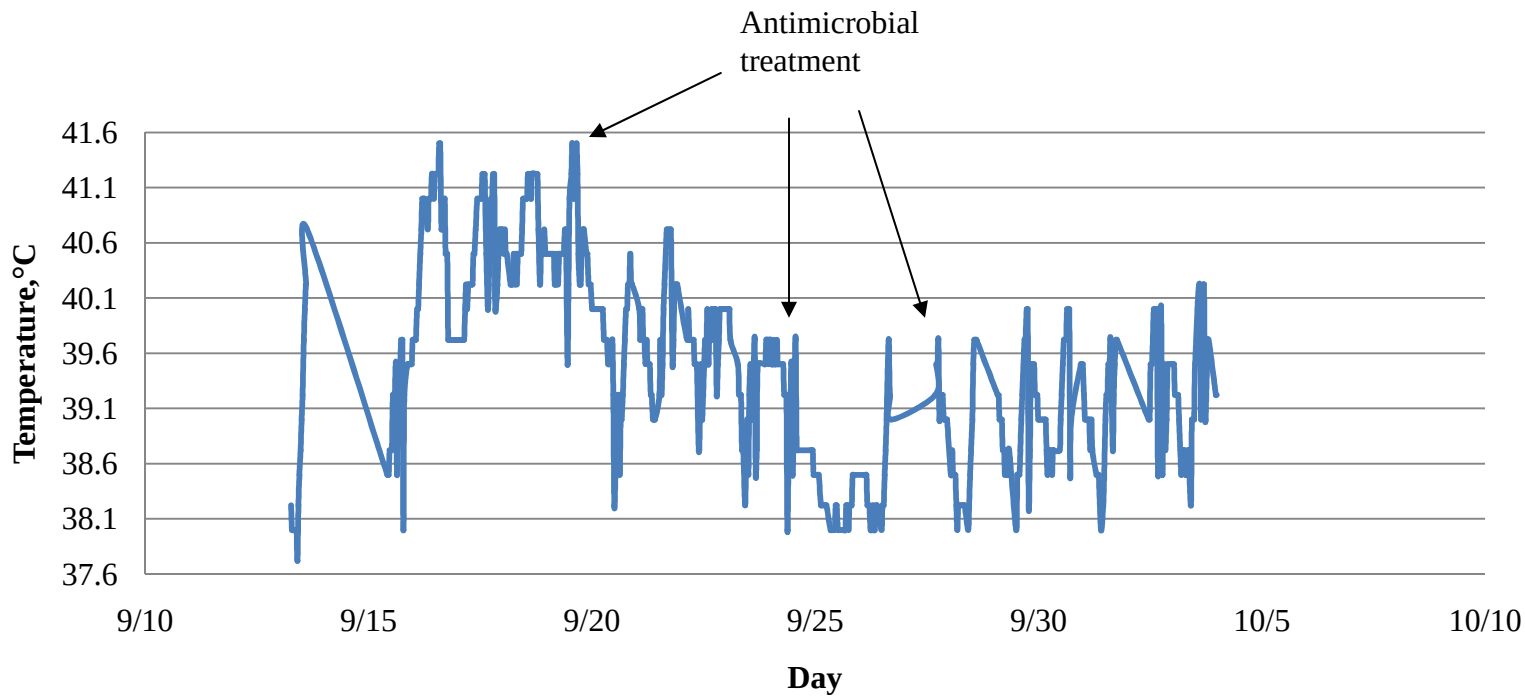

Figure 3. Temperature before and after antimicrobial treatments for BRD signs in an individual calf over 21 d.

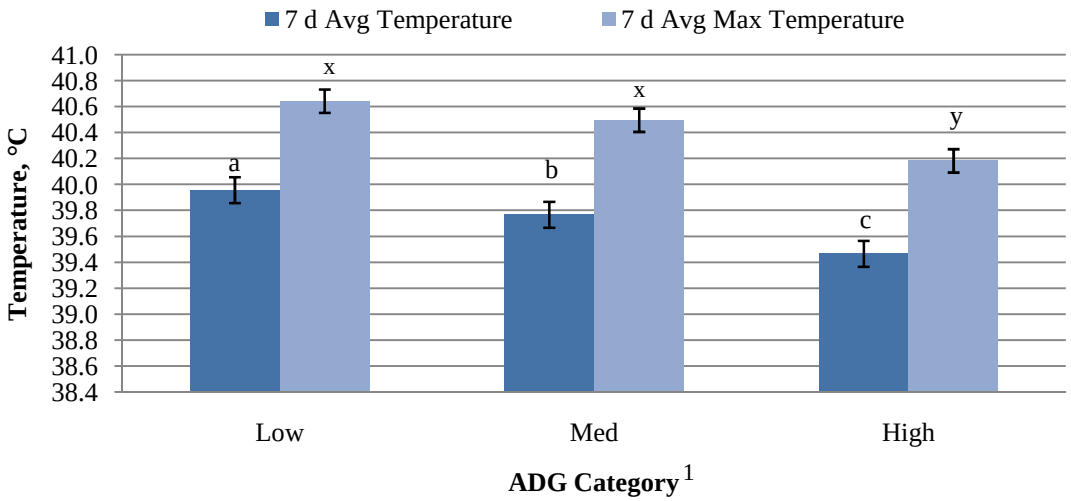

Figure 4. 7-d average and average maximum rumen temperatures of feedlot calves classified by ADG category.
[1] Low (< 0.68 kg), n = 44; Medium (0.68 kg to 1.59 kg), n = 83; and High (> 1.59 kg), n = 41.
[abc]Means within average temperature with different superscripts differ ($P < 0.10$).
[xyz]Means within average maximum temperature with different superscripts differ ($P < 0.10$).

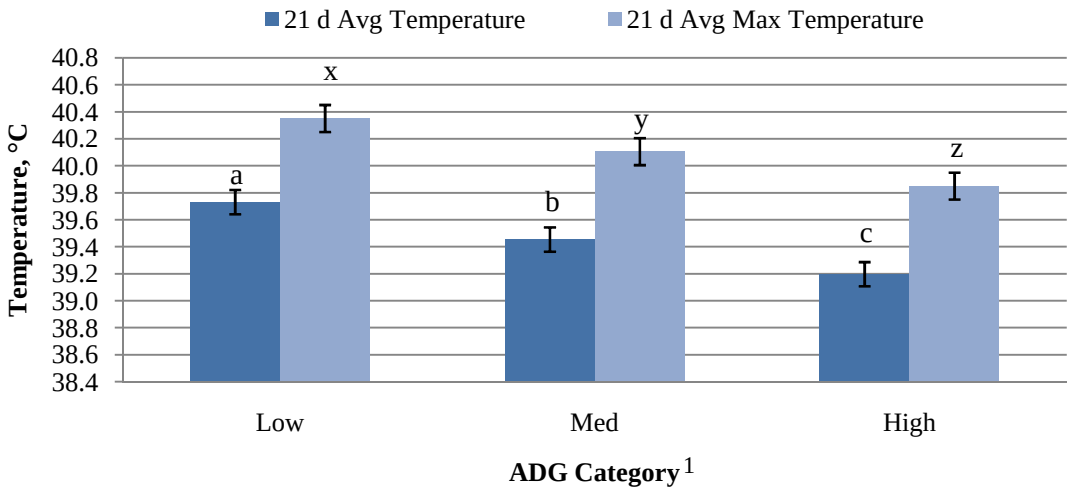

Figure 5. 21-d average and average maximum rumen temperatures of feedlot calves classified by ADG category.
[1] Low (< 0.68 kg), n = 44; Medium (0.68 kg to 1.59 kg), n = 83; and High (> 1.59 kg), n = 41.
[abc]Means within average temperature with different superscripts differ ($P < 0.10$).
[xyz]Means within average maximum temperature with different superscripts differ ($P < 0.10$).

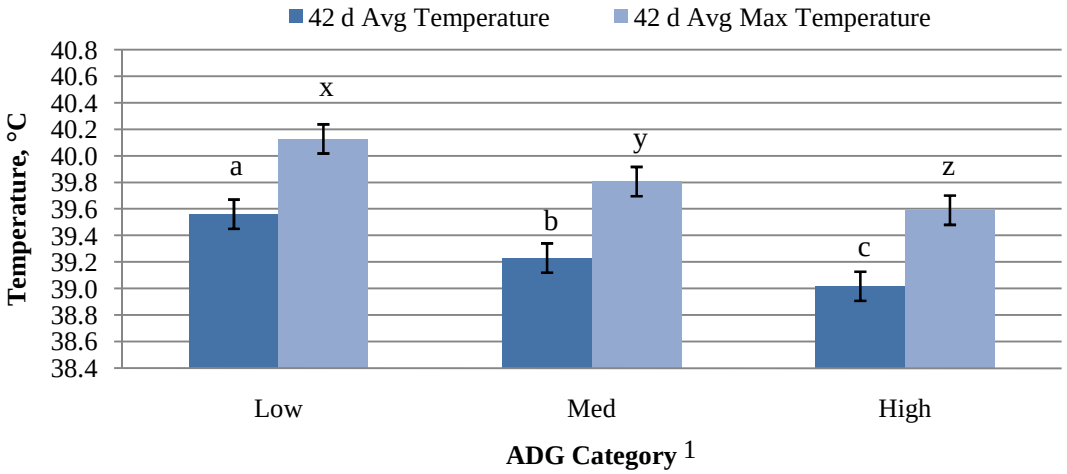

Figure 6. 42-d average and average maximum rumen temperatures of feedlot calves classified by ADG category.
[1] Low (< 0.68 kg), n = 44; Medium (0.68 kg to 1.59 kg), n = 83; and High (> 1.59 kg), n = 41.
[abc]Means within average temperature with different superscripts differ ($P < 0.10$).
[xyz]Means within average maximum temperature with different superscripts differ ($P < 0.10$).

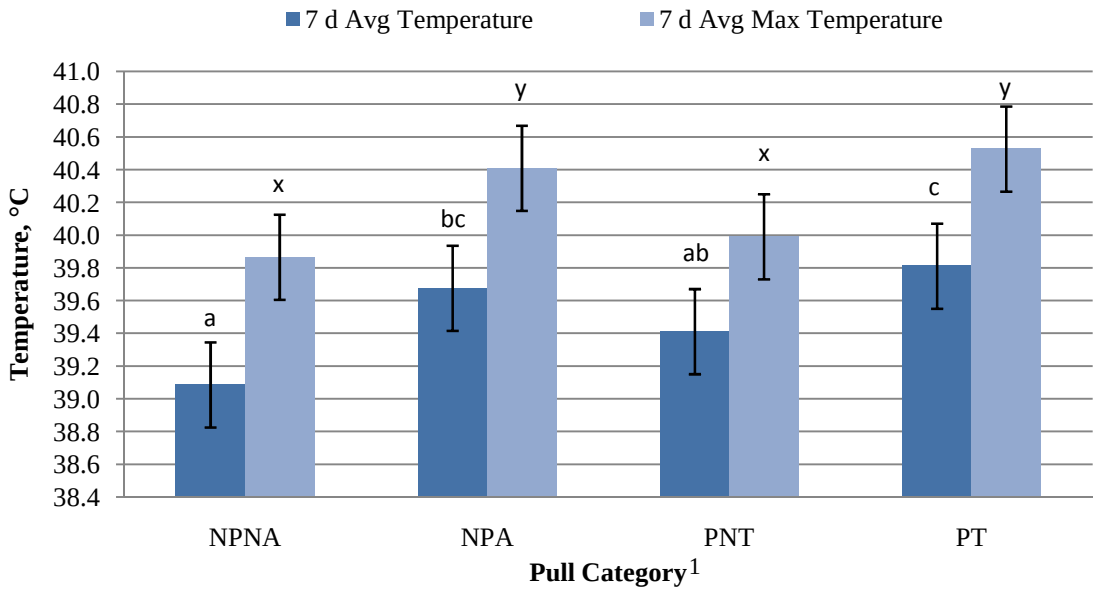

Figure 7. 7-d average and average maximum rumen temperatures of feedlot calves by pull category.
[1]NPNA: never pulled, no alarm (n = 5); NPA: never pulled, alarm (n = 34); PNT: pulled, but not treated (n = 8); or PT: pulled and treated (n = 121).
[abc]Means within average temperature with different superscripts differ ($P < 0.10$).
[xyz]Means within average maximum temperature with different superscripts differ ($P < 0.10$).

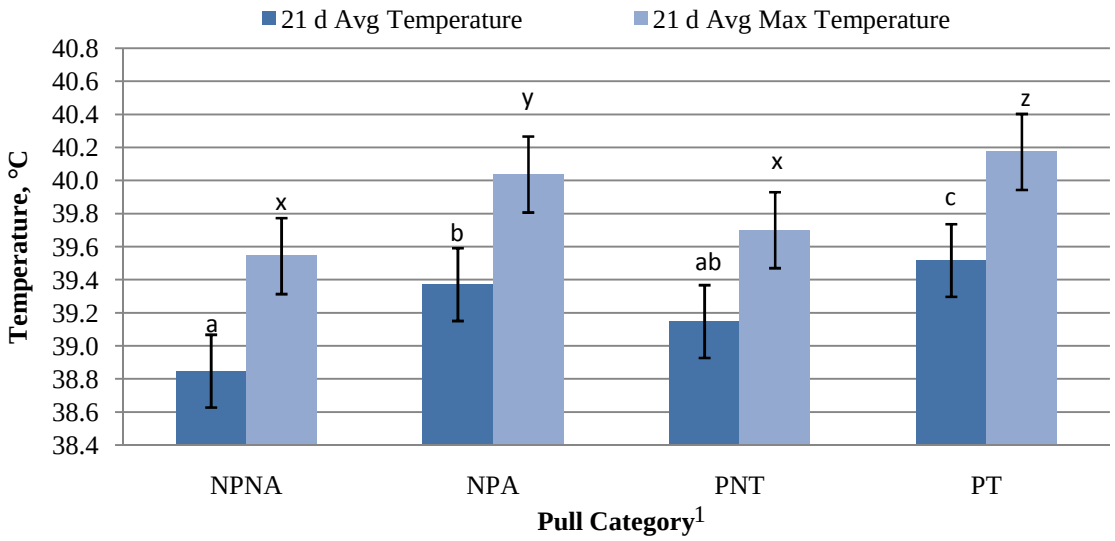

Figure 8. 21-d average and average maximum rumen temperatures of feedlot calves by pull category.
[1]NPNA: never pulled, no alarm (n = 5); NPA: never pulled, alarm (n = 34); PNT: pulled, but not treated (n = 8); or PT: pulled and treated (n = 121).
[abc]Means within average temperature with different superscripts differ ($P < 0.10$).
[xyz]Means within average maximum temperature with different superscripts differ ($P < 0.10$).

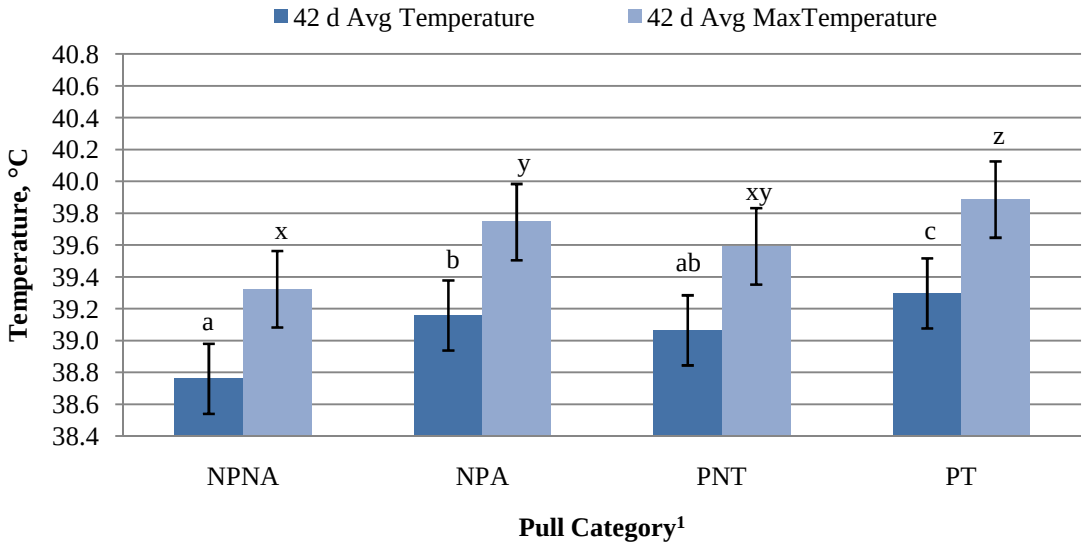

Figure 9. 42-d average and average maximum rumen temperatures of feedlot calves by pull category.
[1]NPNA: never pulled, no alarm (n = 5); NPA: never pulled, alarm (n = 34); PNT: pulled, but not treated (n = 8); or PT: pulled and treated (n = 121).
[abc]Means within average temperature with different superscripts differ ($P < 0.10$).
[xyz]Means within average maximum temperature with different superscripts differ ($P < 0.10$).

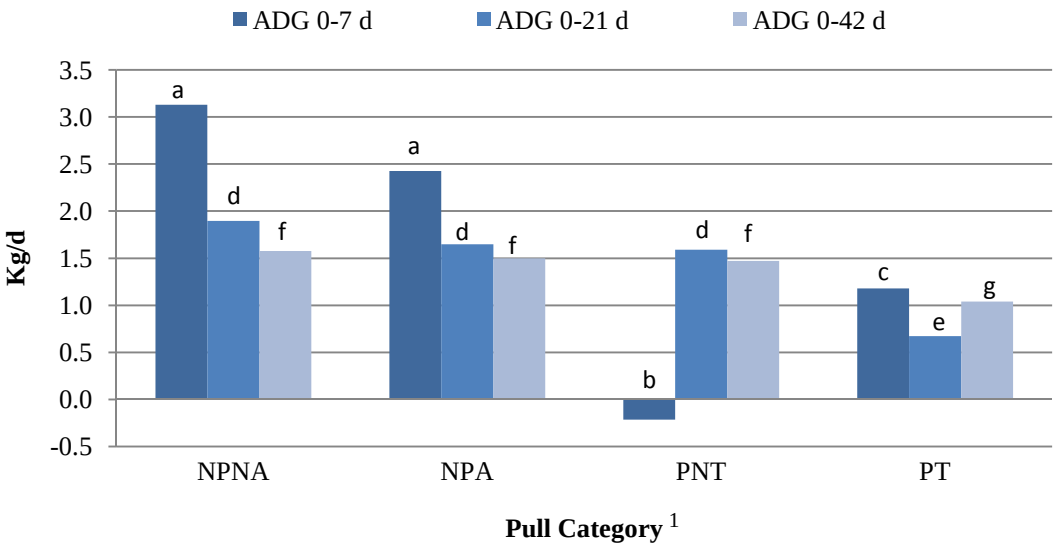

Figure 10. ADG 0-7 d, ADG 0-21 d, and ADG 0-42 d of feedlot calves by pull category.
[1]NPNA: never pulled, no alarm (n = 5); NPA: never pulled, alarm (n = 34); PNT: pulled, but not treated (n = 8); or PT: pulled and treated (n = 121).
[abc]Means within ADG 0-7 d with different superscripts differ ($P < 0.10$), SEM = 0.97.
[de]Means within ADG 0-21 d with different superscripts differ ($P < 0.10$), SEM = 0.51.
[fg]Means within ADG 0-42 d with different superscripts differ ($P < 0.10$), SEM = 0.31.

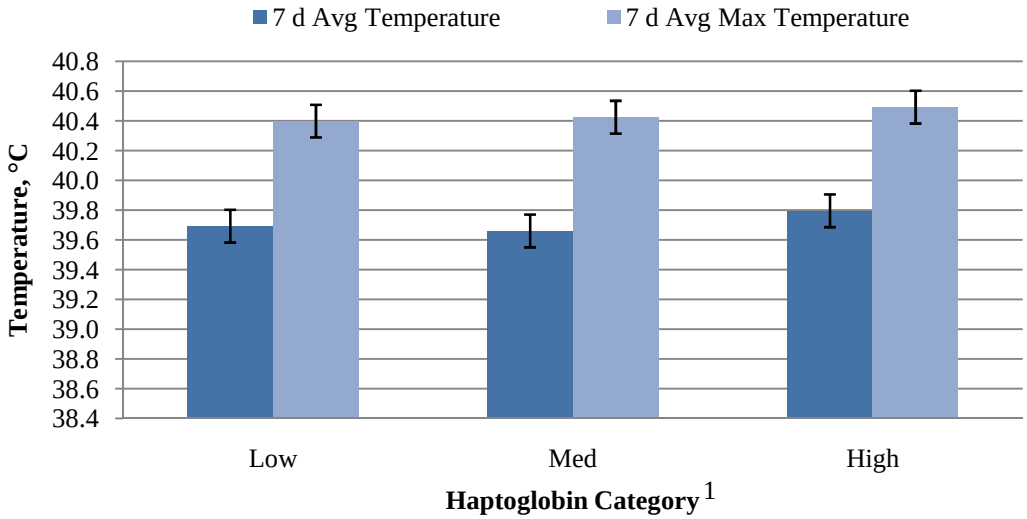

Figure 11. 7-d average and average maximum rumen temperatures of feedlot calves by haptoglobin category.
[1]Low (< 1 µg/100 mL), n = 49; Medium (1 to 3 µg/100 mL), n = 28; and High (> 3 µg/100 mL), n = 91.
No differences were measured between haptoglobin categories.

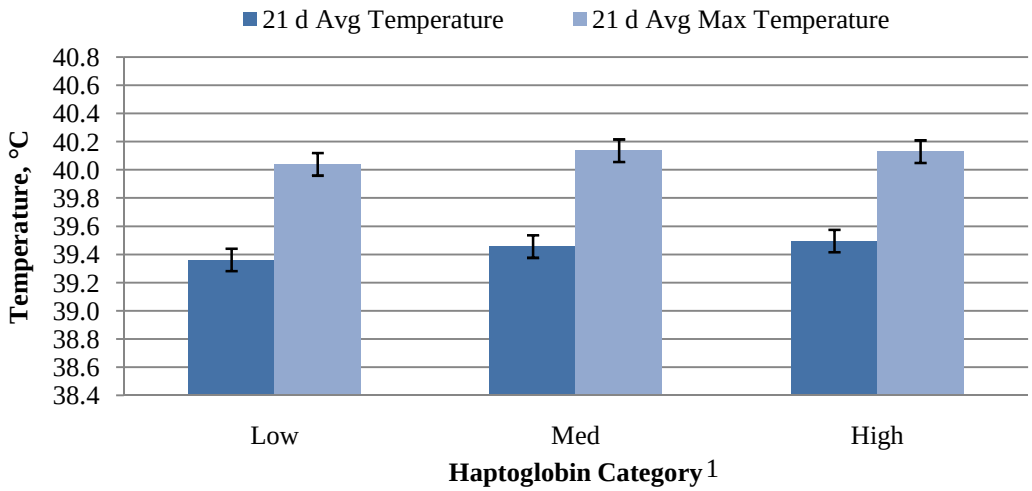

Figure 12. 21-d average and average maximum rumen temperatures of feedlot calves by haptoglobin category.
[1]Low (< 1 µg/100 mL), n = 49; Medium (1 to 3 µg/100 mL), n = 28; and High (> 3 µg/100 mL), n = 91.
No differences were measured between haptoglobin categories.

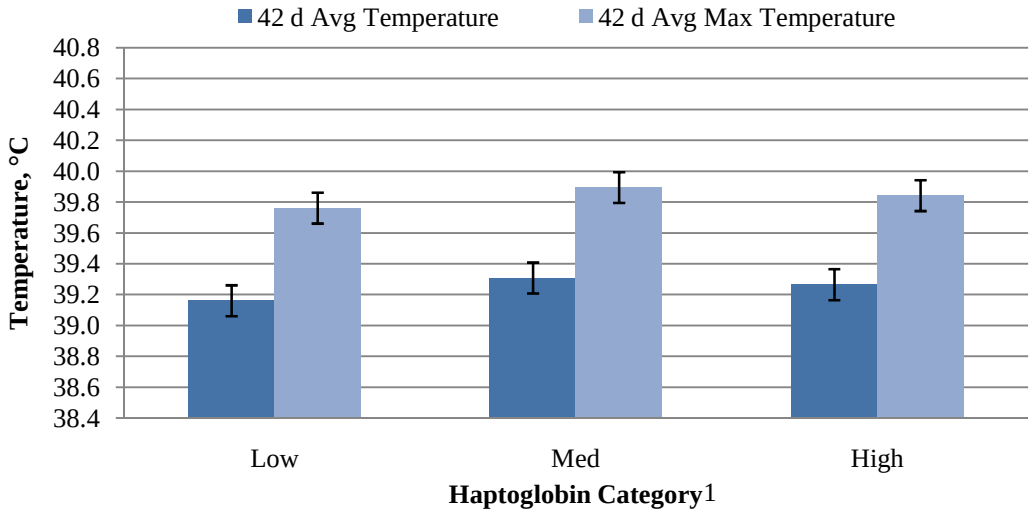

Figure 13. 42-d average and average maximum rumen temperatures of feedlot calves by haptoglobin category.
[1]Low (< 1 µg/100 mL), n = 49; Medium (1 to 3 µg/100 mL), n = 28; and High (> 3 µg/100 mL), n = 91.
No differences were measured between haptoglobin categories.

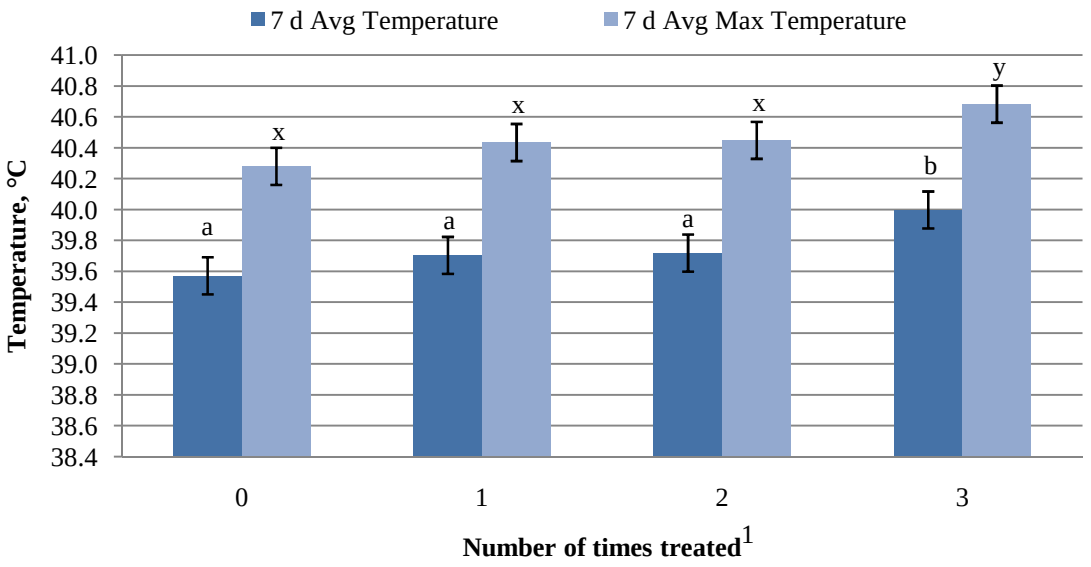

Figure 14. 7-d average and average maximum rumen temperatures of feedlot calves by number of times treated.
[1] 0: n = 47; 1: n = 56; 2: n = 22; 3: n = 43.
[ab]Means within average temperature with different superscripts differ ($P < 0.10$).
[xy]Means within average maximum temperature with different superscripts differ ($P < 0.10$).

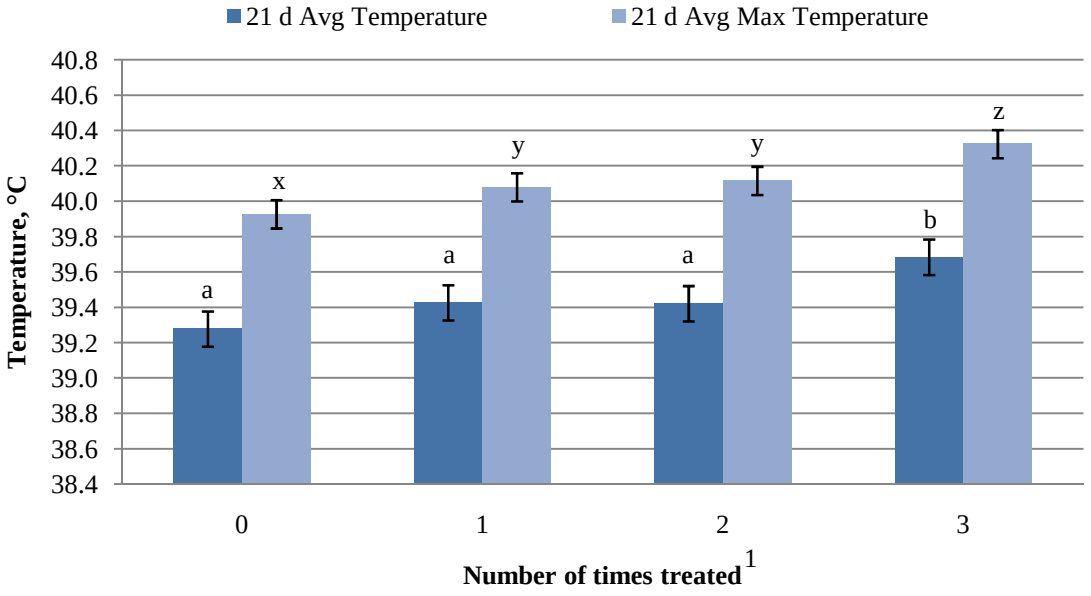

Figure 15. 21-d average and average maximum rumen temperatures of feedlot calves by number of times treated.
[1] 0: n = 47; 1: n = 56; 2: n = 22; 3: n = 43.
[ab]Means within average temperature with different superscripts differ ($P < 0.10$).
[xyz]Means within average maximum temperature with different superscripts differ ($P < 0.10$).

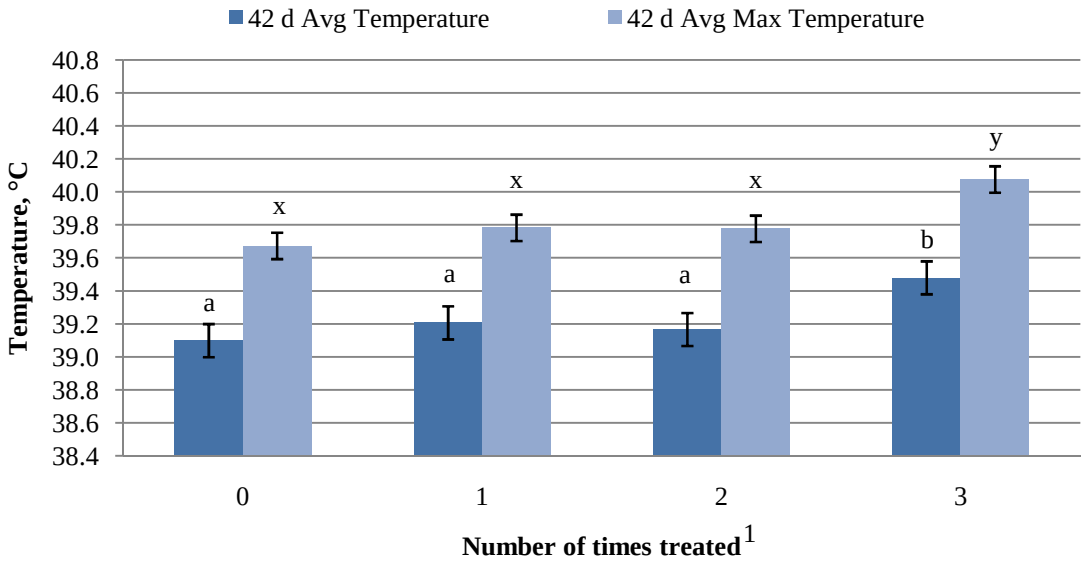

Figure 16. 42-d average and average maximum rumen temperatures of feedlot calves by number of times treated.
[1]0: n = 47; 1: n = 56; 2: n = 22; 3: n = 43.
[ab]Means within average temperature with different superscripts differ ($P < 0.10$).
[xy]Means within average maximum temperature with different superscripts differ ($P < 0.10$).

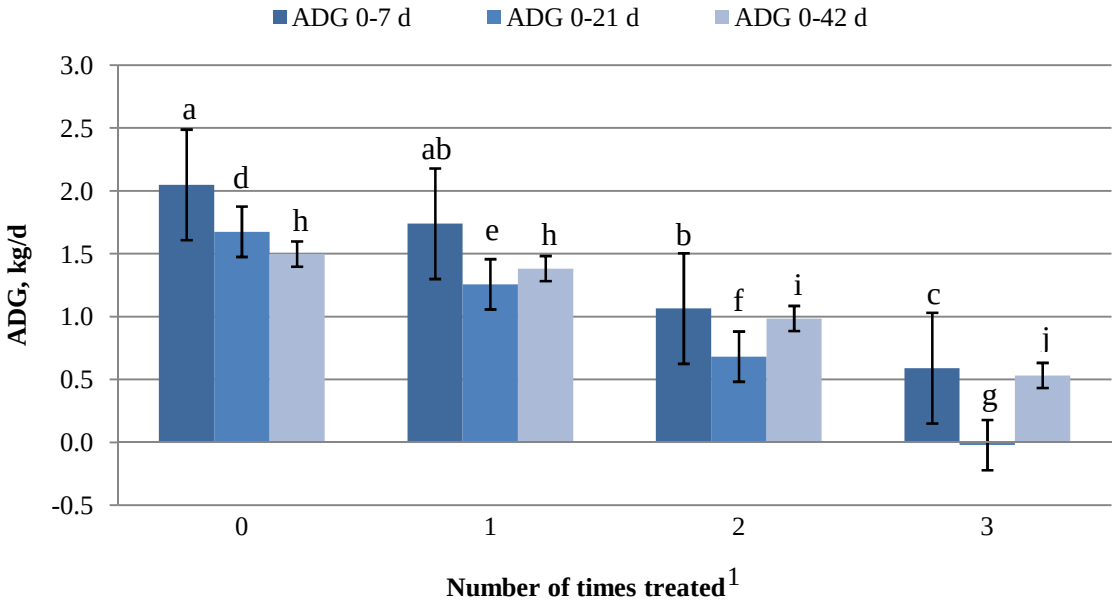

Figure 17. 42-d ADG of feedlot calves categorized by number of times treated.
[1] 0: n = 47; 1: n = 56; 2: n = 22; 3: n = 43.
[abc]Means within ADG 0-7 d with different superscripts differ ($P < 0.10$).
[defg]Means within ADG 0-21 d with different superscripts differ ($P < 0.10$).
[hi]Means within ADG 0-42 d with different superscripts differ ($P < 0.10$).

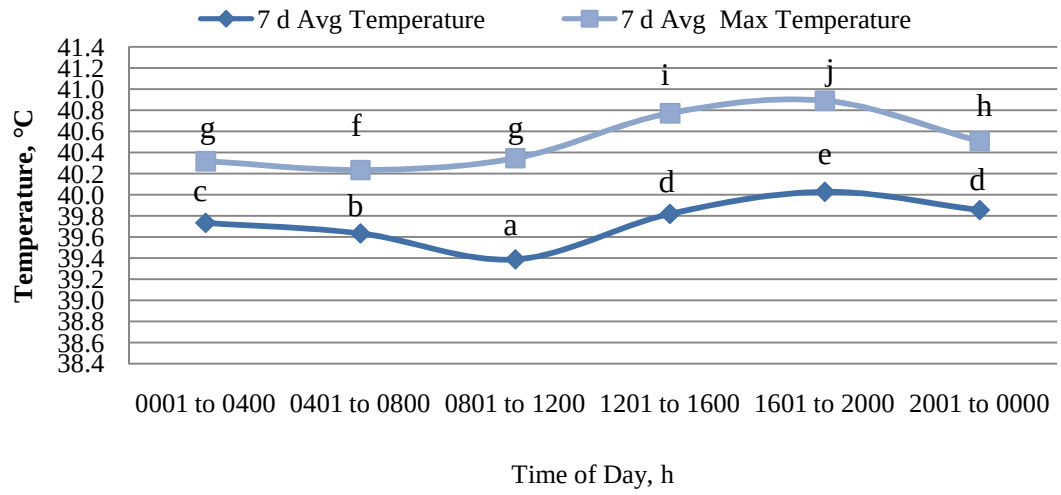

Figure 18. 7-d average and average maximum rumen temperatures of feedlot calves by time of day.
[abcde]Means within average temperature with different superscripts differ ($P < 0.10$; SEM = 0.03) .
[fghi]Means within average maximum temperature with different superscripts differ ($P < 0.10$; SEM = 0.04). n = 168

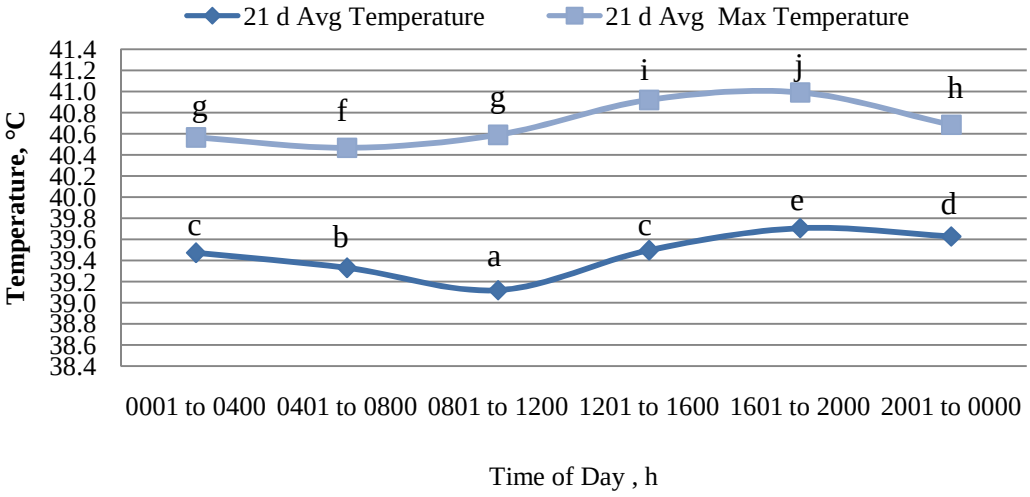

Figure 19. 21-d average and average maximum rumen temperatures of feedlot calves by time of day.
[abcde]Means within average temperature with different superscripts differ ($P < 0.10$; SEM = 0.02).
[fghi]Means within average maximum temperature with different superscripts differ ($P < 0.10$; SEM = 0.03). n = 168

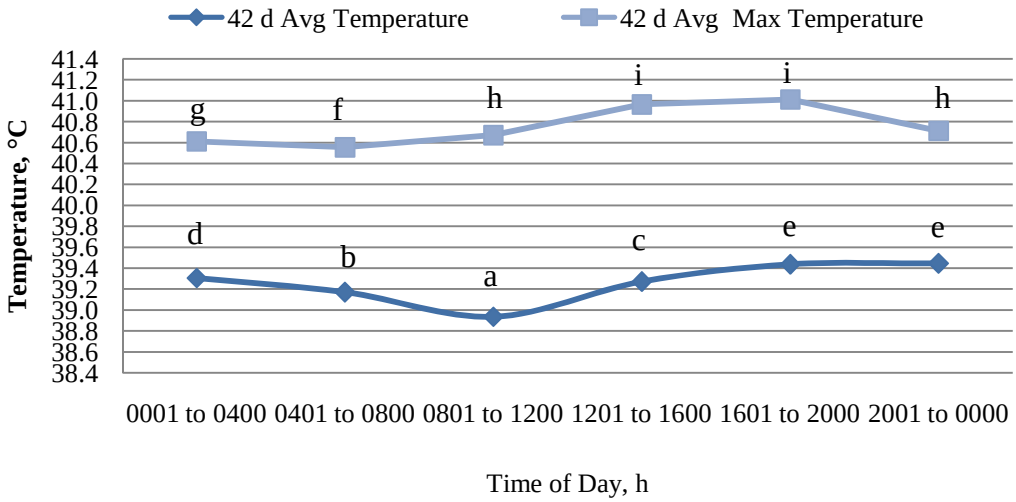

Figure 20. 42-d average and average maximum rumen temperatures of feedlot calves by time of day.

[abcde]Means within average temperature with different superscripts differ ($P < 0.10$; SEM = 0.02).

[fghi]Means within average maximum temperature with different superscripts differ ($P < 0.10$; SEM = 0.03). n = 168

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VITA

Lindsay Eileen Sims

Candidate for the Degree of

Master of Science

Thesis: MONITORING RUMEN TEMPERATURE AS AN INDICATOR OF RECEIVING CALF HEALTH

Major Field: Animal Science

Biographical:

Personal Data: Born in Lafayette, IN, on November 27, 1984 to Rick and Martha Sims

Education: Graduated from Tri-County High School, Wolcott, IN in June 2003. Received Bachelor of Science degree in Animal Sciences from Purdue University in May 2007.Completed the requirements for the Master of Science in Animal Science at Oklahoma State University, Stillwater, Oklahoma July, 2009.

Experience: Raised on a corn and soybean farm in Northwest Indiana. Employed as an undergraduate animal science research assistant in a swine nutrition lab at Purdue University from November 2003 to May 2007. Interned with ADM Alliance Nutrition in Decatur, IN summer of 2007. Currently employed by Oklahoma State University as a graduate research assistant.

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Name: Lindsay Sims Date of Degree: July, 2009

Institution: Oklahoma State University Location: Stillwater, Oklahoma

Title of Study: MONITORING RUMEN TEMPERATURE AS AN INDICATOR OF RECEIVING CALF HEALTH

Pages in Study: 60 Candidate for the Degree of Master of Science

Major Field: Animal Science

Scope and Method of Study: Remote monitored rumen temperature boluses were administered to newly received feedlot heifers to determine their efficacy for monitoring body temperature and detecting heifers with high temperatures related to Bovine Respiratory Disease. A study was completed to determine the efficacy of the rumen temperature bolus system in a feedlot setting with high risk cattle.

Findings and Conclusions: Remote monitored rumen temperature boluses detected increases in rumen temperature when heifers were suspected to be infected with Bovine Respiratory Disease. The rumen temperature bolus system was successfully integrated into a feedlot and resulted in an adequate number of transmissions and showed potential in identifying animals with Bovine Respiratory Disease.

ADVISER'S APPROVAL: _____

Chris Richards, PhD