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An evaluation of the genetic components of bovine respiratory disease and its influence on production traits

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An evaluation of the genetic components of bovine respiratory disease
and its influence on production traits

By

Matthew John Schneider

A thesis to be submitted to the graduate faculty
in partial fulfillment of the requirements for the degree of

MASTER OF SCIENCE

Major: Animal Breeding & Genetics

Program of study Committee:
James M. Reecy, Major Professor
Rohan L. Fernando
James R. Thompson

Iowa State University
Ames, Iowa
2008

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DEDICATION

I would like to dedicate this thesis to both of my parents, John and Carol Schneider. I have been fortunate in my life to have two parents who have shown enormous amount of love and expertise throughout my life. My mom has always been behind me and certainly the first to brag about the accomplishments I have had the opportunity to experience. My dad has given me the desire and the opportunity to learn about all of the aspect of the agriculture world with numerous hands-on experiences. Also, both of my parents have sacrificed so much so that their children could participate and succeed in every activity that we are involved in.
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ABSTRACT

Bovine respiratory disease (BRD) is among the most important infectious disease facing the entire cattle industry. The economic consequences associated with BRD is significant and is one of the most challenging obstacles facing the profitability of cattle operations. Factors that contribute to respiratory diseases in cattle can be broken down into three different segments: viruses, bacteria, and stress. Due in large part to the structure of the U. S. cattle industry, there is no more critical time period cattle face in terms of the overall health and productivity than at weaning and as animals enter the feedlot. The objectives of this study were threefold: 1) to investigate the effects of BRD incidence and number of treatments on economically important performance and carcass traits. 2) to examine the effects lung lesion scores have on important production traits 3) to evaluate the genetic components associated with BRD in both pre-wean and feedlot cattle. In general, the results of this study agree with previous findings of the effect of BRD incidence on production traits, in which greater frequency of BRD treatment is associated with increasing effects on the traits of interest. In terms of lung lesion scores, the only significant differences in the traits of interest were observed when comparing cattle with and without active bronchial lymph nodes. The heritability for BRD incidences in pre-wean cattle was estimated at 0.12 ± 0.06 and 0.08 ± 0.05 for the number of BRD treatments in the current population. Heritability estimates were 0.07 ± 0.04 for BRD incidence and 0.05 ± 0.04 for the number of treatments in feedlot cattle. Though these estimates are low, genetic improvement may be possible through selection programs geared towards BRD resistance in pre-wean and feedlot cattle. Estimates of the genetic correlations between either health measure with hot carcass weight, rib-eye area,
and subcutaneous fat ranged between -0.21 to 0.02; however, the estimate of the genetic relationship of BRD incidence and number of treatments with marbling score was moderate and favorable (-0.42 ± 0.21 and -0.32 ± 0.26, respectively). Genetic selection for BRD resistance may have little effect on hot carcass weight, rib-eye area, and subcutaneous fat cover, but may have a desirable effect on genetic merit for average daily gain, final weight, and marbling score. Reducing BRD incidence would be beneficial in reducing production costs not only in terms of lower disease incidence but also in regard to increasing performance and carcass quality from a genetic merit perspective.
CHAPTER 1.

GENERAL INTRODUCTION

Introduction

Bovine Respiratory Disease (BRD) is the most common and costly health issue in the beef industry. Cost due to BRD can be assessed in the form of increased medication costs, extra labor, veterinary fees, indirect loss associated with lower production and mortality. Annually, approximately 20% of the cattle in the U.S. suffer from BRD at some point in time. BRD effects every phase of production in the cattle industry from the cow/calf producer to feedlot operators. Incidence of BRD can cause a reduction in economically relevant performance and carcass traits. Such traits include weaning weights, final weights, average daily gain, hot carcass weight, while at the same time cattle that have had BRD tend to be associated with less desirable USDA quality grades than cattle not infected with BRD.

The capability of selecting for disease resistance animals to BRD has been implicated from previous research. However, there are many challenging aspects involved with the study of disease resistance such as the low heritability associated with most disease traits as well as the difficultly associated with identifying genetically resistant animals.

In order for cattle producers to remain competitive in the future, it is important that they strive to minimize disease incidence. The healthfulness of animals is more important than ever before because of the ever increasing resistance to current medical treatments and prevention procedures, cost to the industry, and consumer acceptances in
terms of food safety. Researching bovine respiratory disease and the application of genetic improvement programs may ultimately help cattle producers in selection for increased health.

The economic advantage of controlling BRD is applicable to all cattle producers. Therefore, the primary objective of this study was to estimate variance components and heritability of BRD incidence during both pre-wean and feedlot phases of U.S. beef cattle production. This portion of the study included data on cattle from birth to weaning and from entry into the feedlot to harvest, and was accomplished through the collection of treatment records and lung lesion scores at harvest time. The second objective of this study was to examine the effects of BRD on economically important performance and carcass traits, such as weaning weight, warm-up ADG (early feeding period; initial 4 to 6 weeks), on-test ADG (late feeding period; end of warm-up period until harvest), overall ADG (total feedlot period), final weight, hot carcass weight, rib-eye area, subcutaneous fat cover, and marbling score.

**Thesis Organization**

This thesis is composed of an abstract, general introduction, literature review, three individual papers, and a general summary. Each individual paper consists of an abstract, introduction, materials and methods, and results and discussion. References cited in the literature review and the three papers are located at the end of each section, followed by tables and figures. All reference citations follow the regulations set forth by the CBE Style Manual used by the Journal of Animal Science to which these papers will be submitted.
CHAPTER 2.
LITERATURE REVIEW

**Bovine Respiratory Disease**

Bovine respiratory disease which is commonly referred to as BRD is an infectious disease which wreaks havoc on the entire cattle industry year after year. Bovine respiratory disease is certainly an infection that does not discriminate, but rather it affects all cattlemen in every phase of production, from cow/calf to feedlot. Due to the enormous economic losses associated with treatment and prevention, lower performance, and less desirable carcass traits, this disease is the most costly health issue facing the cattle industry (Snowder, 2005b).

**Factors Contributing to Bovine Respiratory Disease**

Factors that contribute to respiratory diseases in cattle can be broken down into three different segments: viruses, bacteria, and stress. Interestingly enough, many normal cattle actually carry bacterial and viral agents within their body systems without expressing any effect until they are stressed (Bagley, 1997), which then allows for replication of these causative agents. Stress factors that are commonly associated with BRD include, but certainly are not limited to: extreme heat and cold, dust, dampness, humidity, dehydration, hunger, anxiety, nutritional deficiencies, transportation, overcrowding, and commingling cattle from different sources. Common viral agents that are implicated in BRD include infectious bovine rhinotracheitis (IBR), bovine viral diarrhea virus (BVDV), bovine respiratory syncytial virus (BRSV), and parainfluenza type 3 (PI-3). In addition, bacterial strains associated with BRD include *Mannheimia*
haemolytica, Pasteurella multocida, Haemophilus somnus, and mycoplasma (Ellis et al., 2001; Plummer et al., 2004).

Cattle that are thought to be at high risk have a greater chance of experiencing respiratory problems; consequently special attention should be taken to ensure an environment that maximizes health. Factors that contribute to cattle that are thought to be at high risk includes: season, as more calves get sick during the fall months, weight of calves, as cattle weighing less than 450 kg are more at risk to contract BRD, (Edwards, 1996; Currin and Whittier, 2000), and age, as young calves respiratory systems may not be fully developed (Lekeux, 1995). Additionally, calves not weaned prior to shipment, cattle from an auction market, and bull calves that haven’t been castrated are at much higher risk for BRD (Edwards, 1996; Currin and Whittier, 2000).

Viruses responsible for BRD have a variety of distinguishing characteristics. Infectious bovine rhinotracheitis usually affects the upper respiratory tract and is notorious for its role in causing shipping fever along with other pathogens (Dryer, 1981). Parainfluenza type 3 is often found in young calves and is the most widespread viral agent associated with respiratory disease found throughout the cattle industry (Dryer, 1981). Bovine respiratory syncytial virus is extremely prevalent in the cattle industry, found in 38 to 76% of cattle herds (Dryer, 1981; Richey, 2002). Bovine viral diarrhea virus which is unique in the fact that it consists of two biotypes referred to as Cytopathic and Noncytopathic as well as two genomic types, Type I and Type II (Atkins, 1999; Ridpath, In Press). The difference between cytopathic and noncytopathic viruses is the nonstructural protein known as NS2-3 seen in the cytopathic BVDV (Ridpath, In Press). Noncytopathic BVDV has been isolated more frequency than cytopathic with BVDV1
noncytopathic being isolated more often than BVDV2 (Fulton et al., 2000b; Fulton et al., 2002). Bovine viral diarrhea virus is diversified in that it can have harmful affects to the respiratory, digestive and reproductive systems which can make cattle susceptible to many other pathogens. Therefore, one of the biggest problems with BVDV is the fact that infection with this virus is commonly seen in combination with other pathogens (Fulton et al., 2000a).

Despite the frequency in which viral agents are seen the most prevalent organism in cattle is a bacteria, *Mannheimia Haemolytica* (Duff and Galyean, 2007). As previously mentioned, it is not uncommon for healthy cattle to carry bacterial agents within their nasal cavities without any adverse effects until a combination of viral agents and stress causes pneumonia and shipping fever as other parts of the respiratory tract are made vulnerable to the power of this potentially deadly partnership (Collier, 1968; Dryer, 1981).

**Clinical Signs**

Cattle of all ages can be affected by respiratory disease; however they are the most susceptible during the decay of passive immunity in young calves, weaning time, and entrance into the feedlot as cattle are introduced to a wide range of stress and pathogens (Muggli-Cockett et al., 1992). The format of the U. S. cattle industry is set up in a manner that many cattle face weaning, transportation, and introduction into the feedlot at subsequent intervals, thus bovine respiratory disease is often referred to as “shipping fever.” The most common symptoms associated with BRD includes: breathing difficulty such as noisy rapid breathing, coughing, decreased appetite, lethargy, droopy ears, eye discharge, fever, nasal discharge, open mouthed breathing, and death. BRD
symptoms are numerous and diverse. Therefore, diagnostic of BRD can sometime, be troublesome. For this reason, it is common practice to classify cattle as suffering from respiratory disorders if animals are expressing any combination of these symptoms along with rectal temperature of greater than or equal to 40 degrees C° (104 F°) (Duff and Galyean, 2007). If cattle producers use this diagnosis procedure, it is important to realize that the body temperature of cattle can change depending on the time of day temperature is taken. In order to obtain a more accurate measurement a calf’s temperature, it should be taken before 10 am (Currin and Whittier, 2000), to avoid the excessive heat experienced throughout the day.

**Economic Importance & Impact**

Bovine Respiratory Disease is the leading cause of illness found in the United States cattle industry (USDA APHIS, 2001). The cost to the U.S. cattle industry has been estimated at $750 million per year (Griffin, 1997). Much of the cost of disease incidence occurs because of losses dealing with mortality, lower performance, costs for treatment, and reduced carcass values such as lower marbling deposition (Roeber et al., 2001). The beef industry is the single largest enterprise within the agricultural section representing $188.4 billion to the U.S. economy (Otto and Lawrence, 2001), and the economic damage associated with BRD is certainly devastating to the overall wellness of the agricultural community.

Productivity in the beef industry has been improving over time. The U.S. beef herd has experienced a drop of total number of cows of 11% since 1980; however, there has been a 22% increase in production during this same time period (Otto and Lawrence, 2001). Much of the improvement in production has likely come from improved genetics,
nutrition, and management which in turn lead to greater stress on the immune system of cattle. This may help explain the increase in BRD incidence (Babcook et al., 2006) experienced in the cattle industry as well as the increase of deaths contributed to respiratory disease from 52.1% in 1994 to 61.5% in 1999 (USDA NAHMS, 2000).

Bovine respiratory disease incidence has been reported to range between 5 to 50% in different populations (Kelly et al., 1986; Bateman et al., 1990; Wittum et al., 1996; Bryant et al., 1999; Gardner et al., 1999; Snowder et al., 2006b), and this range can change drastically depending on many environmental, management, and epidemiological factors. In a study by USDA APHIS (2001), the percent of cattle placed in feedlots that are affected by bovine respiratory disease was at 8.7% for 1,000 – 7,999 head feedlots and 15.5% for feedlots with over 8,000 head with an overall incidence rate of 14.4%, which is close to five times the next most common disease. The consequences of BRD far outweigh that of other disease facing the U.S. cattle industry.

BRD is the most devastating disease in the beef industry and obviously the most severe risk of respiratory disease is death. Death losses related to disease problems causes significant economic loss throughout the cattle industry and a great deal of this loss can be attributed to respiratory problems. This is evident by the fact that 27.4% or 1,110,000 head of the 4,051,000 reported cattle deaths in the United States in 2005 were due to respiratory problems coming to a total value to the industry of $692,430,000 (USDA NASS, 2006). This economic value is close to double of the second most costly factor in cattle death loss in the United States, which is digestive problems at $367,441,000 (USDA NASS, 2006). Death loss regarding respiratory disease is seen in all segments of the cattle industry. The total death loss due to respiratory reasons in 2005 of cows, bulls,
as well as steers and heifers weighing over 500 pounds was 37.7%, whereas claves which includes steers, heifers, and bulls weighing less than 500 pounds comes to 62.3% (USDA NASS, 2006). Mortality is a huge cost in terms of bovine respiratory disease and there is evidence to show that the rate of mortality is rising within the U.S. cattle industry (Loneragan et. al., 2001; Babcock et al., 2006). In a large study that looked at the trends of mortality among U.S. feedlots with a total record of 21,753,082 cattle, mortality was seen in 1.26% of cattle with respiratory representing 57.1% of all deaths and mortality rates increased from 1994 to 1999 by 38% though not quite significant (P=0.09). At the same time the proportion of death caused by respiratory reasons was significantly increased during this time period (Loneragan et al., 2001). It is also logical to assume that morbidity of BRD during this time period would expect to rise since there is a clear connection between morbidity and mortality in regards to BRD.

Certainly much of the cost of respiratory disease is due to the expense of the actual treatment of disease. Estimates of the cost to treat one incidence of respiratory disease have been estimated to range from $12.39 to $15 (Faber et al., 1999; USDA APHIS, 2001; Edwards, 1996). This estimate only includes cost of pharmaceuticals, syringes, and needles but does include the loss of production such as labor fees, lower performance and indirect loss due to lower carcass values. Another study has estimated the indirect loss of economic value due to reduced average daily gain, using the combination of clinical and sub-clinical BRD incidence rate determined by health treatments and lung lesion of $1.79 per calf that entered a feedlot (Thompson et al., 2006). Still, when medicine costs as well as lower carcass weights and values are considered the economic loss is increased drastically as steers that have not been treated
for BRD were worth $57.48 (Faber et al., 1999) more per head than for treated steers, and steers without lung lesions have been estimated to be worth a net return of $20.03 (Gardner et al., 1998), more than steers with lesions. In comparison, this same value quickly jumps to a return of $73.78 when steers without lesions are compared to steers with lesions and active lymph nodes (Gardner et al., 1998).

Bovine Respiratory disease can certainly have a profound effect on performance of cattle. BRD has been shown to cause an increase in mortality rates, reduce average daily gain, increase of days on feed, and poorer carcass values such as hot carcass weight and marbling scores (Wittum et al., 1996; Gardner et al., 1999; Roeber et al., 2001; Fulton et al., 2002;). Calves diagnosed with BRD were 7.7 kg lighter than healthy calves at weaning and an overall death loss of 1.4% (Snowder et al., 2005). Other factors contributing to higher disease incidence is commingling of cattle, which has resulted in a 120% increase in chronic disease in commingled cattle, compared to pens with cattle from a single source (O’Connor et al., 2005). Another important factor associated with increase BRD incidence is calves experiencing difficult at births associated with dystocia. These calves were more prone to BRD and younger at diagnosis compared to calves experiencing no complications at birth (Muggli-Cockett et al., 1992; Snowder et al., 2005). In perhaps the most detailed study of the costs associated with disease, the Texas A&M University Ranch to Rail program researched the cost of finishing cattle for 10 years. McNeill et al. (1992-2001), reported the difference of return between healthy calves and those requiring treatment from $49.55 to $151.18 with an average of $91.77. This difference in value between healthy and sick cattle can be attributed to increases of 0.136 kg per day in average daily gain for healthy animals with lower death loss and
improved carcass quality compared to treated cattle McNeill et al. (1992-2001). In addition a loss of 0.04 kg of ADG associated with treated cattle was also seen in Snowder et al. (2005b), research.

There is certainly a difference in return when you start to analyze the number of treatments calves receive and profit is extremely important to the U.S. cattle industry. Calves that were not treated returned $40.64 more than calves treated once, $58.35 more that calves treated twice, and $291.93 for calves treated three times or more (Fulton et al., 2002). This was primary due to the added cost of medicine as well as the lower carcass grades that was significantly different for animals treated 2 or more times than calves not treated (Fulton et al., 2002). This same story holds true in the Texas A&M Ranch to Rail study which reported that healthy steers gained 1.33 kg per day compared to 1.26 kg per day in sick calves and 39% of healthy cattle graded U.S. choice or better compared to 27% of sick cattle with a overall difference of $92.26 in profit with healthy cattle and only $31.00 was due to medicine (McNeil et al., 1996), and in later years the value of healthy versus sick cattle came to $61.87 due only to indirect loss such as reduced performance, increased feed cost of gain, lower quality grades (McNeill et al., 1992-2001). Waggoner et al., (2007), also estimated the gross income for healthy cattle at $59.47 per head mainly due to less death and higher carcass prices warranted by healthy cattle. In yet another study, the BRD incidence rate of 16.9% was seen in a total of 6,618 head of cattle. Cattle treated, though not limited to respiratory disease, experienced significantly lower marbling scores in cattle treated once and even lower for those treated twice, and treated two or more times reducing Choice grade by 52%, 45.8%, and 12.3% respectively compared to non-treated cattle (Busby et al., 2004). It is easy to notice the
cost of medicine in treating cattle, but the real advantage to healthy cattle comes from improvements in production traits such as efficiency, higher gains, and increase in sale values.

**Preventative Methods & Treatments**

The best defense that cattle producers have against BRD is prevention. Taking steps to ensure prevention is extremely important because of the possibility of an epidemic outbreak and thus economic ramifications that BRD presents. Prevention of BRD is best accomplished through vaccination and management, specifically, paying close attention during high stress periods particularly during weaning and shipping to feedlot (Bagley, 1997). In terms of the feedlot, there is plenty of evidence to suggest that most of the respiratory incidence occur within the first few weeks upon entering the feedlot (Sowell et al., 1999; Snowder et al., 2006b; Snowder et al., 2006c; Thompson et al., 2006). As cattle enter the feedlot, there is an increase in the number respiratory incidences which occurs because of the high susceptibility cattle face during times of stress (Bryson, 1985). In a study completed by Thompson et al. (2006), the peak day of BRD treatment occurred on Day 18 after entry into the feedlot and remained high until Day 35 when there was a rapid decline. There have also been reports of greater reduction of ADG in early feeding periods than in later time periods due to BRD incidence (Bateman et al., 1990; Van Donkersgoed et al., 1993; Faber et al., 1999; Thompson et al., 2006). Therefore, it is extremely important that feedlot managers pay close attention during this time period. The consequences of treatment early in a calf’s life can be seen in the negative effects on carcass characteristics at a much later time period such as harvest (Stovall et al., 2000). Thus, driving home the point that the time immediately following
cattle entrance into the feedlot is extremely critical to monitor health extensively due to the added stress of transportation and commingling of new cattle.

One of biggest obstacles in the effort to reduce BRD incidence is the fact that even though 96.9% of feedlot farms vaccinate for at least one causative agent to BRD only 28.4% cow/calf producer vaccinate (USDA APHIS, 1997; USDA NAHMS, 2000). The lack of respiratory vaccination during the early phases of a calf’s life is concerning, especially since it has been shown that proper vaccination of BRD in cattle certainly is beneficial. In one study Nyamusika et al. (1994), compared the cost and benefits of respiratory vaccination by an empirical mathematical model of BRD and showed that a typical Midwestern feedlot could expect a return $40 from vaccinated cattle and $44 for vaccinated cattle that are treated as clinical signs arise. There is no doubt that the positive return on vaccination should be stressed when persuading cattle producers to vaccinate.

The most widely used methods for treatment of a BRD outbreak is the use of injectable antibiotics. More specifically, the most common antimicrobials being used for initial treatment for BRD is tilmicosin, florfenicol, and tetracyclines with each being used 31.1%, 21.9%, and 21.6% of the treatments, respectively (USDA APHIS, 2001). It is also common practice for cattle producers to use more than one product upon initial treatment for BRD with the most common combinations consisting of an injectable antimicrobial used with either oral antimicrobial, respiratory vaccine or Non-steroidal anti-inflammatory drug (USDA APHIS, 2001).

Feedlot personnel face many challenges due to the lack of past health and management information of newly received cattle. According to the USDA APHIS (2000b), only 32.4% of feedlots always or at least most of the time received information
regarding the preconditioning information of their cattle, whereas 16.2% or 32.4% never or only sometimes receives information on the preconditioning treatment of cattle, respectively. When feedlots were surveyed about the knowledge of preconditioning procedures of the last shipment of cattle they received 30.7% did not have any information if cattle had been vaccinated against any respiratory disease and 30.9% did not know if they were introduced to a feed bunk USDA APHIS (2000b). In contrast, only 53.1% were certain that the last shipment of cattle they received had been vaccinated and at the same time only 39.2% were aware of cattle being introduced to a feed bunk USDA APHIS (2000b). In two other studies, it was clear that there was a lack of communication between the cow/calf producer and feedlot managers as it was reported that only 20% of calves can be traced back to their original source (Herrick, 1969). Purdy et al. (1987) showed that the percentage of cow/calf producers in seven Southeastern states who vaccinate for a pathogen related to BRD was only between 10.3 to 27.6%. The information that feedlot personnel receive regarding the pre-health and management strategies of cattle could prove valuable in their production decisions and ability to prevent BRD associated economic loses.

**Implementation of Management Decisions**

Preconditioning is a viable option for cattle producers to utilize in order to minimize the stress cattle face when entering feedlots later in life. These types of programs usually involve introduction to a feed bunk, castration, dehorning, parasite treatment, and proper vaccination (Nyamusika et al., 1994). There is good evidence that shows the advantages in health and performance of cattle placed in preconditioning environments; however, most cattle producers are not taking advantage of this procedure.
One reason is the lack of economic incentive for cow/calf producers to take on the added cost of feed, labor, and vaccination, while with the current market system in place in the cattle industry the feedlot owners receive the rewards (Nyamusika et al., 1994; Currin and Whittier, 2000). Majority of feedlot personnel view there are many management steps that can be taken in pre-feedlot arrival cattle to reduce sickness and death loss seen throughout the feedlot. These steps include: introduction to the feed bunk, respiratory vaccine either two weeks prior to or at weaning, calves weaned four weeks prior to shipping, and calves castrated and dehorned prior to shipping (USDA APHIS, 2000a). If producers decide to implement preconditioning to their calves, it is important that they do not allow their cattle to get too “fleshy” (TAMU, 2005; “fleshy” is defined as cattle in excellent body condition in terms of fat cover), as this could further increase input cost and result in reduced retail price. A successful preconditioning period should result in average daily gains typically around 1.0 to 1.5 pounds per day (TAMU, 2005).

Preconditioning is not a new practice to the cattle industry as it has been implemented in some cattle operations for decades. No one single reason can be used to explain the lack of acceptance of preconditioning cattle, but certainly the lack of an overall method to document this program and thus a way for cow/calf producers to reap the rewards of the added risk they take on with this kind of operation. Many studies have been involved in showing producers the advantages of preconditioning, and perhaps the most intriguing have estimated the premiums paid to cow/calf producers anywhere between $0.041 to $0.121 per kg (McKinnon and Greiner, 2002; Avent et al., 2004), or a net return of $14.16 taking into account the added cost and extra premiums associated with preconditioning (Dhuyvetter et al., 2005).
In order for these premiums to be realized at the feedlot, personnel will have to be convinced of the increased return at finishing associated with preconditioning cattle. Roeber and Umberger (2002) showed that two groups of preconditioned cattle had a higher return at slaughter time of $46.83 and $49.54 compared to two groups of cattle of unknown health and processing history. Cravey (1996) showed similar results with a return of $60.72 for preconditioned cattle. One of the biggest questions regarding the benefits of preconditioning is how much lower disease incidence is expected? There was a reduction in disease incidence of 41.6% in the average of two groups of precondition cattle compared to cattle coming from an auction market (Roeber and Umberger, 2002). In addition, calves that are not weaned or weaned very shortly to feedlot arrival are as much as 3.4 more times likely to have a BRD incidence compared to calves weaned more that 30 days (Faber et al., 1999). The research that is available certainly gives light to the advantages of preconditioned cattle.

In cases where cattle are considered high risk some cattle producers use mass medication or Metaphylaxis in order to fight off an outbreak of BRD. Mass medication can drastically reduce morbidity. Lofgreen (1983) used long acting oxytetracycline in combination with sustained-release sulfadimethoxine to reduce morbidity from 63.3% in control calves to 7.1% in mass medicated calves. Reducing BRD incidence with mass-medication of tilmicosin phosphate (Micotil) has been shown to be effective as well (McCoy et al., 1994; Morck et al., 1993; Merrill et al., 1994; Galyean et al., 1995). Galyean et al. (1995) reported that mass medication of Micotil based on rectal temperature is just as effective, thus resulting in a much lower number of calves being treated, 42%, compared to 100% of calves mass medicated. Still, Metaphylactic treatment
of both tilmicosin and florenicol in combination of chlortetracycline decreased morbidity and improved average daily gain in a 21 day period (Daniels et al., 2000) and on average calves treated with these injectable antibodies were worth $7.02 more than control cattle. In addition, mass treatment of florenicol shortly after cattle arrived to the feedlot decreased Mannheimia haemolytica in the nasopharynx and delayed the onset of respiratory diseases (Frank et al., 2002).

Another aspect to mass medication is answering when the most appropriate time to implement this procedure is. One study showed treating cattle with mass medication of tilmicosin phosphate prior to transportation and upon arrival reduced BRD incidence compared to control, but the two time periods did not differ significantly (Frank and Duff, 2000). Based on this result the timing of mass medication could be left up to the convenience of the cattle producers involved.

Certainly there are drawbacks to the use of mass medication. These include high medical cost and concerns about antibiotic resistance associated with this procedure, therefore it has been suggested that mass medication should only be used on high risk cattle where at least a BRD incidence rate of 30% would be expected (Currin and Whittier, 2000). Also, cattle producers who wish to use mass medication need to consider that treatment through feed additives may not reach the cattle whom would benefit the most from medication as these animals tended to visit the feed bunk in less frequency early after arrival (Sowell et al., 1999; Buhman et al., 2000). Many of the management decisions that cattle producers must make are extremely difficult and sometimes the research available is conflicting. With this in mind, if cattle producers use their expertise in animal husbandry in combination with expertise from their veterinarians and
nutritionists they are more likely to develop the most optimal environment to raise their cattle.

**Antimicrobial Resistance**

The excessive use of antibiotics throughout the cattle industry and even the use of mass medication only increase the risk of antimicrobial resistance, which is becoming an increasing larger issue facing the livestock industry (Axford et al., 2000). Another issue contributing to antimicrobial resistance is that there has not been a new class of antibiotics discovered in the past three decades (Detilleux, 2001). Pharmaceutical sales in the livestock industry are not monitored and animal antimicrobial can be purchased over the counter unlike that of human medicine. Therefore, it is extremely important that individual producers work to reduce and eliminate the unnecessary use of excessive antimicrobial use. Such practices that could be utilized to reduce the dependency we currently have on antibiotics include: limiting the availability of antimicrobials, assuring optimal colostrum intake, increasing the use of vaccines, and on-farm interventions like, introducing only new animals from herds of known health status, and quarantine of new animals (USDA APHIS, 2000c).

One of the most important aspects to fighting off pathogen infection for young calves is passive immunity received from the mother. It has been noted in U.S. dairy herds that if adequate amount of colostrum are consumed as much as 22% of dairy calf deaths could be prevented (USDA APHIS, 1993). Because of the different structures of the beef and dairy herd, it is nearly impossible to estimate this same figure in the beef industry; however, this certainly sheds light on the importance that consumption of colostrum has on a new born health status. In terms of vaccination, an amazing 86% of
beef calves in the U.S. are not getting adequate protection against respiratory pathogens (USDA APHIS, 1993).

Reduction of antibiotics has been shown to be effective in Sweden without any production loss (Wierup, 1997). Implementing methods to assure optimal passive immunity transfer to calves and increasing preventive methods such as vaccination could help in reducing antibiotic use in the U.S. Another key to lowering the use of excessive antibiotic use is the diagnosis of BRD of animals as early in infection as possible. This would help to overcome the disease before it has time to cause unrepairable damage to the calf’s immune system and prevents an epidemic outbreak within the population. Someday advances in technology may someday be utilized more effectively to help cattle producers implement early detection. Infrared thermography (Schaeffer et al., 2005) and radio frequency used to monitor body temperature (Reid and Dahl, 2005) may be possible methods in early detection. The addition of animal identification to the U.S. cattle industry may some day prove beneficial in assisting the acceptance of such technologies.

**Behavioral Effects**

It is true that most animal handlers observe cattle on a regular basis looking for one or more of the common clinical signs associated with BRD before they take action in treating animals. Now this is certainly an appropriate action to take; however, there is growing evidence that sick animals feeding and drinking behavior can differ drastically from healthy animals. By observing the actual behavioral of cattle, producers may be able to diagnosis sick animals prior to any clinical signs.

There is growing evidence that the number of times an animal eats and the duration of eating differs among sick and healthy cattle (Sowell et al., 1999; Buhman et
More specifically, sick cattle ate significantly less feed during 11 to 27 days after arrival into a feedlot (Buhman et al., 2000). Also calves observed to have no or minor pulmonary lesions at slaughter ate more often and longer than cattle with severe pulmonary lesions during the 11 to 27 days after arrival however this was reversed during days 28 to 57 days after arrival (Buhman et al., 2000). It was suggested that this change may be due to compensatory gain of sick animals, higher maintenance requirement, or even slow feed consumption rate.

It was also reported that drinking behavioral of sick calves was significantly higher in frequency and length 4 to 5 days after arrival (Buhman et al., 2000). However, in contrast Basarab et al. (1996) showed that calves morbid for BRD spent 23.7% less time at drinking than healthy cattle with an 81.5% accuracy level for detecting BRD. In addition, Sowell et al. (1999) reported there was no difference in drinking behavior. The different outcomes in these studies in terms of drinking may be attributed to the differences in management, environment, beginning weight of cattle and varying levels of BRD incidence seen. The use of feeding behavioral in diagnosis of cattle suffering from BRD may be a more adequate method which can help to determine animals that subsequently will be affected by this disease and prevent misdiagnosis and feedlot personnel should take into account the decreased feed intake of stressed cattle when determining their feed rations (Galyean et al., 1999). Certainly more research is warranted to determine to what degree these factors are associated with BRD incidence.

**Lung Lesion Effects**

One of the growing concerns of traditional diagnosis of bovine respiratory disease is the inability to accurately determine all cattle that truly were affected by BRD. For this
reason lung scoring of cattle in combination of health records is becoming increasing popular in order to identify both clinical and sub-clinical BRD. It has been reported that lung lesions are actually a better indicator of lower ADG than health records (Wittum et al., 1996; Bryant et al., 1999).

Lung lesions present at slaughter can range anywhere between 33% to 87% (Wittum et al., 1996; Bryant et al., 1999; Buhman et al., 2000; Epperson, 2003; Thompson et al., 2006). What is interesting to point out is that 29% to 68% (Wittum et al., 1996; Gardner et al., 1999; Bryant et al., 1999; Thompson et al., 2006), of animals that had never been treated for BRD had lesions presents at harvest. Either animals are simply not showing significant enough symptoms to be diagnosis or cattle handlers are missing sick cattle in their health assessment. In comparison the animals that expressed lung lesions at harvest, 69.5% had never been treated for BRD (Thompson et al., 2006), and this was nearly identical (70%) in Wittum et al. (1996). Still, even more interesting facts are discovered when we begin to look into the cattle that were treated for BRD. Here we see that cattle treated at least once and had lung lesions at harvest range between 27% to 55.4% (Wittum et al., 1996; Bryant et al., 1999; Thompson et al., 2006). This percentage of lung lesions may be explained by the ability of treatment to reduce lesion or the fact that animals were simply misdiagnosed. These findings clearly demonstrate the inadequately of simply using only health records to distinguish between healthy and sick animals. In combination all animals that either were treated or had lung lesions was estimated at 52.5% (Thompson et al., 2006), which represents the true overall BRD incidence rate compared to only 22.6% clinical diagnosis of BRD.
Lung lesions are of serious concern, because of the loss of production seen from cattle with lesions present. Many studies have estimated the reduction of average daily gain of 23 g (Thompson et al., 2006), 26 g (Bryant et al., 1999), 76 g (Wittum et al., 1996), and 180 g (Gardner et al., 1999). Lung lesions have also been associated with a 5.5 day increase in days on feed (Thompson et al., 2006), and at the same time cattle without lung lesions have higher dressing percentage, heavier carcasses, more external fat, larger longissimus muscle area, and more desirable carcass grades (Gardner et al., 1999). When clinical and sub-clinical cattle have been studied there have been no difference in average daily gain during the entire finishing phase; however, clinical BRD did result in lower gains during the early phase of feedlot exposure with a reduction of 216 g compared to sub-clinical BRD with a reduction of 91 g (Thompson et al., 2006). The differences among the two feeding phase indicated compensatory gain was achieved through the use of successful treatment.

Many lung scoring systems have been used and enormous amount of research has been dedicated towards determining the most effective scoring system. Bryant et al. (1999) suggested that lesions in the cranial ventral lung lobes are the most helpful in determining sub-clinical BRD as well as the effect on average daily gain. This is further supported by Epperson (2003) who suggested that scoring done at chain speed of only the right cranial and right middle lobes would diagnose 86.1% of lung lesions. The lack of fully developed respiratory system make young cattle extremely vulnerable to affects of BRD (Lekeux, 1995), thus special attention needs to be made to ensure the health of these cattle for their entire lives.
**Immune Response**

Immune response is an important aspect to the prevention and reduction of disease in the cattle industry, and selection of animals for greater responsiveness to vaccination is possible (Wilkie and Mallard, 1999). Selection for improved immune responses has been completed in poultry (Leitner et al., 1990; Yonash et al., 1994), sheep (Bishop et al., 1996; Bouix et al., 1998), and pigs (Mallard et al., 1998; Wilkie and Mallard, 2000). The idea of increasing resistance by immune response will have to be weighed against the cost to mount a sufficient immune response against the cost of impact of infection (Bishop and Stear, 2003). Since the effect of BRD has on the cattle industry is quite large, it is logical to assume that any discoveries in improving immune response would be beneficial; however, there may be many challenges as a trait this complex is likely influenced by many genes (Glass, 2004).

One of most important factor in lowering BRD in young calves and yet is also one of the biggest obstacle involved in immune response to vaccination is the presence of passive immunity. Passive immunity is handed down to the young calf through the cows ability to transfer antibodies colostrum (Ellis et al., 2001). Inadequate transfer of passive immunity is associated with more than 5 times greater risk of mortality, and over 3 times greater risks of morbidity during the pre-weaning period. At the same time, morbidity increases after weaning (Wittum and Perino, 1995). Another study showing the importance of passive immunity was conducted by Martin et al. (1988), whose results indicated that the presence of titer for BRSV in cattle not vaccinated decrease the risk of cattle suffering from respiratory disease. These findings stress the importance of identifying calves at risk of not meeting adequate passive immunity such as calves born
from first calf heifers. The presence and quality of maternal immunity is one of the most important defense cattle have at a start of a healthy disease free life.

Many studies have been dedicated to determining the time frame that maternally passed antibodies begin to fade in young calves as well as a reasonable level of antibodies for response to vaccination to be effective. A study by O’Neil et al. 2007 showed that cattle that were between 60 to 167 days old at vaccination indicated that pre-existing antibodies must be reduced to 1:8 to 1:16 for at least 90 percent of calves to respond positively to BRSV and PI3 by 28 days post-vaccination. Calves seronegative to BVDV 1 and 2 had a seroconversion to vaccination in 100% of BVDV 1 and 91.3% of BVDV 2 calves 32 days after vaccination occurred (Kirkpatrick et al., 2001). It was also suggested that vaccination should be used at early ages (60 days) to ensure cattle are protected from the important time period when passive immunity is running low. This early vaccination will result in either a seroconversion, prime the immune system, or no response.

The problem with passive immunity titers in calves comes from the interference they may have on vaccination and thus the lack of a calf’s own immune response when high titers are present before vaccination (Fulton et al., 2004). The amount of time it takes the passive immunity of IBR, BVDV 1, BVDV 2, PI3, and BRSV to decay in calves has been measured to be 65.1, 117.7, 94.0, 183.8, and 200.2 days respectively (Kirkpatrick et al., 2001). The decay figures for BVD are similar to other reports, where it was estimated between 105 to 230 days of age (Kendrick et al., 1974; Menanteau-Horta et al., 1985). Obviously the passive immunity decay rate for each important pathogen involved with BRD varies from animal to animal and this fact is very important in
determining the proper time to vaccinate young calves. In fact, calves from younger cows experience higher pre-weaning BRD but lower post-weaning frequencies than calves from older cows possibility due to lower colostral antibody in the pasture but less interference of passive immunity and higher vaccination response during the feedlot phase (Muggli-Cockett et al., 1992).

Deciding the proper time to vaccinate young calves can be a challenge, however there is evidence that neonatal calves that have been deprived of colostrums are capable of expressing a favorable immune response to a *Pasteurella haemolytica* vaccine (Hodgins and Shewen, 2000) while experiencing less lung damage, higher survival rate, and less clinical scores after challenge. This is important to show that even the very youngest cattle can and will respond to vaccination if there is no passive immunity to causes problems. Since there are many important pathogens involved with BRD, it is important that the use of vaccinations with more than one antigen is effective. This has been conducted by a study on the initial titer level on arrival and the seroconversion therefore on seven pathogens related to BRD showed that the titer of one pathogen did not appear to be negatively associated with the titer of another pathogen (Martin et al., 1989). Adjuvants are being used in vaccination products in order to eliminate the interference seen with vaccination antigens and maternal antibodies. In one study the use of a modified live virus (MLV) with adjuvant was used to test its effectiveness in young calves that were challenged with BVDV type 2. Vaccinated calves that had high maternal antibodies present at 4 to 5 weeks had lower body temperature, fewer clinical signs, and fewer deaths, and protection was seen even when challenged 4 to 5 months later. (Zimmerman et al., 2006).
The immune response is also extremely important to feedlot producers not only as the cattle enter the feedlot, but also because many producers use vaccination against BRD themselves. As cattle come into the yard, it has been shown that cattle with higher levels of BVDV 1 antibodies was related to low morbidity and deceased net value was also related to low levels of antibody for *P. multocida*, BVDV1a and BVDV2 (Fulton et al., 2002). Another study reported that lower BVDV antibody titer upon arrival to the feedlot was associated with an increase in temperature (Booker et al., 1999). Antibodies for BVDV 1 could be used as a predictor of illness. One study indicated that BVDV 1 antibodies were significantly different between healthy cattle and cattle that were treated one or more times (Fulton et al., 2002). The same trend was seen with BVDV 2, antibodies although it was not quite significant (P<0.06) (Fulton et al., 2002). Bovine viral diarrhea virus is a pathogen that is involved with BRD and previous exposure to BVDV prior to entering a feedlot was associated with lower BRD risks (O’Connor et al., 2001). The use of MLV with BVDV type 1 can be effective in protecting against strain of BVDV type 2 (Cortese et al., 1998; Ellis et al., 2001).

It is common practice to use serum antibodies as a way to measure cattle immune protection; however, there is evidence that this method is not sufficient and that cell mediated immunity may be a more approximate method to measure immune response (Ridpath et al., 2003). As cattle arrive in the feedlot, it is common practice to vaccinate cattle against bovine respiratory disease. One decision that must be made is to use either MLV or killed vaccination. Both MLV (Ellis et al., 1992) and inactivated vaccine (Ellis et al., 2005) have been shown to be effective in producing an increase in virus neutralizing antibodies as well as decrease lung lesions and reduce virus shedding (Ellis
et al., 2005). It is also encouraging that the use of MLV can be used to increase immune protection without adverse effects on performance (Horne et al., 2007). Despite cattle producers’ efforts to reduce the risk of BRD in the herd, some animals will become sick and never respond to treatment.

**Persistently Infected Cattle**

No matter how many times some cattle are treated, they always seem to be sick. Persistently infected is a condition that happens to cattle when noncytopathic infection occurs in the first 125 days in utero. During gestation the fetus recognizes the BVDV virus as part of its own immune system and thus becomes tolerant to this virus (Ridpath, In Press). Suckling PI calves are an extreme determent to herd health due to the fact that these calves are exposed to the herd early in pregnancy and they constantly shed the virus throughout their lives. Determination of PI calves is extremely important in the diagnosis and removal of these animals from the herd to prevent spread of BRD. PI calves can be detected by taking an ear notch of each calf (Loneragan et al., 2005). PI has a profound effect on the prevalence of bovine respiratory disease and has an overall prevalence within the cattle industry of 0.3% to 0.4% and 2.6% and 2.5% within chronically ill and dead cattle (Loneragan et al.; 2005; Fulton et al., 2006).

Persistently infected cattle can live a full life all the way to breeding age without being detected and in fact, 33% of PI cattle lived until two weeks prior to slaughter (Loneragan et al., 2005). Therefore, exposure to PI cattle occurs over an extremely long frame with new arrivals to a feedlot constantly being exposed since the cattle industry does not operate on an all-in all-out procedure. Exposure to a PI calf affects both pen mates and adjacent pens, resulting in a 43% greater risk of initial treatment for BRD
(Loneragan et al., 2005). Persistently infected cattle are also effective in starting infection in susceptible cattle and vaccination shortly before exposed to PI cattle is not sufficient to prevent infection (Fulton et al., 2005). Cattle that are PI face another challenge, that being Mucosal disease which causes severe diarrhea, fever, anorexia, depression, nasal discharge, gastrointestinal hemorrhages, and ulcers. This disease results in death and is contracted when a PI calf comes into contact with cytopathic BVDV.

Cattle producers in the U.S. face many questions in reducing the prevalence of BRD throughout the cattle industry. One possible method would be to rid the industry of PI cattle. Removal of PI is the leading effort in eradication of BVDV in Scandinavian countries; however, the cattle industry is different than here in the U.S. because of relatively low BVDV presentence and low density of cattle (Ridpath, In Press). In order to minimize the effects of BVDV, cattle producers have many decisions to control this pathogen either through total eradication, or vaccination and careful management (Brownlie, 1995). There are many difficulties with a total eradication plan; however, the use of vaccination and PI testing certainly will be beneficial to reducing the prevalence of PI cattle here in the U.S.

**Disease Resistance**

The breeding of disease resistance has been a popular topic in a wide range of diseases in livestock species. It has been shown that breeding for disease resistant for Marek disease (Cole, 1968; Steadham et al., 1987; Pinard et al., 1993), nematode infection (Bisset and Morris, 1996), scrapie in sheep (Belt et al., 1995), mastitis (Heringstad et al., 2000), cattle ticks (Utech et al., 1978), E. coli strains in pigs (Edfors-Lilja and Wallgren, 2000), and enhanced immune responsiveness (Mallard et al., 1998;
Wilkie and Mallard, 2000) have been shown to be successful. The efficiency or rate of progress for genetic improvement of selecting for disease resistance is largely depend on the heritability of the trait or traits used to measure disease resistance along with amount of genetic variation among animals (Stear et al., 2001). Heritability estimates for diseases based on health records in cattle have been estimated for displace abomasums, ketosis, mastitis, lameness, cystic ovaries, and metritis (Zwald et al., 2004a; Zwald et al., 2004b) as well as bovine keratoconjunctivitis in pre-wean calves (Snowder et al., 2005a), and bovine respiratory disease (Snowder et al., 2005b; Snowder et al., 2006b). Heritability of immune response traits can also be substantial and selection for enhanced immune responsiveness has been predicted to influence broad based disease resistance (Mallard et al., 1998; Wilkie and Mallard, 2000).

Selection for disease resistance can be implemented in a number of ways. Some examples of this would be to observe for diagnosis of disease, challenge all animals, challenge relatives to breeding stock, observe pathogen products, and finally examine biological and immune response (Snowder, 2006a). One of biggest question in regards to disease resistance is whether to breed for resistant or tolerance. Selection for resistance is defined as an animal’s ability to resist infection, whereas tolerance is the animal’s ability to withstand pathogenic effects of infection (Bishop and MacKenzie, 2003). Breeding for resistance animals could surely lower the transmission of the disease and lower the ramifications of disease on the population. There is no doubt that breeding for resistant is difficult to implement but epidemics of disease outbreak can be reduced without making the whole population resistant (MacKenzie and Bishop, 2001). Whereas tolerance would certainly lower the impact of infection, it would not have an effect on the spreading of
disease throughout the livestock industry. Other challenges of research involving disease resistance is that not all animals may be exposed to pathogens evenly, sub-clinical infections may be present, and the difficulty of correctly identifying the disease present (Snowder, 2006a).

Also causing issue with breeding for disease resistant is the possible antagonistic genetic relationship between many disease traits and production traits. One thought is that selecting for disease resistant for one disease might lead to an increase in another disease. Raadsma et al. (1997) looked at the relationship among resistance to many diseases in sheep and found the genetic relationship tended to be neutral or favorable, which means breeding for resistant in one disease will not increase susceptibility to other disease. McEwan et al. (1992) came to the same conclusion in researching the relationship of egg counts in different species of nematodes in sheep. Antagonistic genetic relationships also refer to the unfavorable relationship between disease incidence and production traits (Rauw et al., 1998; Stear et al., 2001), such as has been reported in milk production, with disease records for ketosis, mastitis, lameness, and milk fever (Simianer et al., 1991; Rauw et al., 1998; Kadarmideen et al., 2000; Fleischer et al., 2001; Hansen et al., 2002). There has also been unfavorable relationship between nematode egg counts with wool growth and body weight in sheep (McEwan et al., 1995; Coop and Kyriazakis 1999), and selection for increased growth rate depressed immune performance (Miller et al., 1992). In contrast resistant to disease do not necessarily show reduced production. That is evidence of a favorable relationship between increase in immune response and higher performance in sheep (Bishop et al., 1996; Bouix et al., 1998), and pigs (Mallard et al., 1998; Wilkie and Mallard, 2000).
Sorting through all of the information available of disease resistance is difficult and the varying reports of favorable and unfavorable relationship between production traits and disease resistance makes this process even more challenge. For this reason, it has been suggested that genetic selection on a multiple trait model for predicting resistance in regards to a category of disease rather than by individual disease may be more effective (Zwald et al., 2004b). Selecting for disease resistant on an individual disease basis is even more difficult if there is a low heritability, which is generally the case in disease resistance. Using a number of diseases to calculate heritabilities may assist in increasing heritability (Zwald et al., 2004a). This is why selection index may be the best solution to select for improvement in both performance and health indices (Gibson and Smith, 1989), and should be used to include traits with unfavorable associations and maximize the desired responses while attempting to minimized undesirable effects (Stear et al., 2001). Health traits should be in selection programs because of the possibility of unfavorable genetic correlations (Simianer et al., 1991; Lund et al., 1999), and improvement could be achieved in health traits (Kadarmideen et al., 2000). Selection index methodology has already been developed to put weight on traits by their economic merit (Cameron, 1997).

In regards to bovine respiratory disease, individual genetic variation exits and breeding for genetic improvement for disease resistance could be beneficial. Heritability of BRD resistance has been estimated at 0.10 (Muggli-Cockett et al., 1992), as well as 0.07 and 0.19 (Snowder et al., 2005b), in pre-wean cattle with an underlying heritability for incidence of BRD estimated at 0.48 (Snowder et al., 2005b). Heritability of resistance to BRD in the feedlot ranged from 0.04 to 0.08 (Muggli-Cockett et al., 1992; Snowder et
al., 2006b; Snowder et al., 2006c), with a heritability of 0.18 using an underlying continuous normal scale (Snowder et al., 2006b). Heritability estimates for BRD can be raised with higher disease incidence years because more animals are able to truly express their phenotype to disease incidence by more challenge (Snowder et al., 2006b). This could be applied to the Mugggli-Cockett et al. (1992) study as more incidence of disease occurred in the preweaning period, resulting in a larger heritability compared to the post-weaning. Snowder et al. (2005b) also observed that heritability during years of low incidence ranged from 0.06 to 0.11 and increased during years of high incidence ranging from 0.12 to 0.25. Not all animals need to be resistant to BRD for the selection to be effective, instead a sufficient number of animals resistant to the disease need to be present to decrease spread among susceptible animals (Anderson and May, 1992; Bishop and MacKenzie et al., 2003).

It is suggested that there may be differences in the resistance as well as sensitively to BRD amongst breeds (Snowder et al., 2005b). Incidence rate was the highest in Braunvieh at 18.8% and ranged from 8.34 to 18.85% in all other breeds with an overall rate of 10.52%. Among cattle with BRD, Simmental cattle faced the highest mortality rate of 17.7% with Limousin facing the lowest at 7.0% (Snowder et al., 2005b). The breed differences in morbidity and mortality indicate some breeds may be more sensitive to disease where as others may be more resistant to infection (Snowder et al., 2005b). Breed differences were also significant for BRD frequency during the pre-weaning and post-weaning phases. Braunvieh (20.1%) and Pinzgauer (13.2%) had the highest incidence during pre-weaning. Pinzgauer (24.6) had the highest BRD incidence rate during post-weaning and Angus (11.8), Limousin (12.4), Charolais (13.4), Gelbvieh
(13.4%), and Red Poll (13.9%) had the lowest incidence during the same time period (Muggli-Cockett et al., 1992). Research on BRD resistance in crossbred cattle has been conflicting to date. There was evidence of heterotic effects on variation of BRD incidence (Muggli-Cockett et al., 1992), in one study. In contrast, heterozygosity did not have a significant factor on resistant to BRD (Snowder et al., 2006).

Selection for resistance to BRD would have negligible effects on growth, carcass, and LM palatability traits due to the small and nonsignificant estimates of genetic correlations but did have an effect on decreased carcass weight and percentage of retail product (Snowder et al., 2007). In another study, there was a favorable genetic correlation between daily gain and energy intake with respiratory thus suggesting genetic improvement of disease resistance can be expected when breeding for these beef production traits (Wassmuth et al., 2000). However, one complication to breeding for disease resistance was that there was a large negative genetic correlation between direct and maternal genetic effects. It was reasoned that the dams that were more resistant provide their calves with more superior passive immunity thus delaying the onset of the calf own immune system. (Snowder et al., 2005b). Certainly more research regarding this topic will help to determine the factors involved in reducing bovine respiratory disease and overcome the challenges the cattle industry faces.

Producer data can be useful for genetic selection to reduce disease (Zwald et al., 2004b; Snowder et al., 2006b). Though improvements in BRD resistance could be made using health records, it may be slow and should use other phenotypes in combinations with health records for selection (Muggli-Cockett et al., 1992). Evidence has already indicated that there is a difference in breed of cattle and the immune response particularly
between Angus and Simmental cattle as the humoral immune response was greatest in Angus cattle (Engle et al., 1999). This information is encouraging as we begin to look into the future of breeding for disease resistance.

*Estimation of Additive Genetic Variance for Categorical Traits*

Bovine respiratory disease is classified as an extreme case of a categorical trait, because of the nature in which we define disease incidence as either healthy or sick. The analysis of categorical traits can be difficult and many problems arise due to the skewed distribution properties that are involved with categorical traits (Gianola, 1980; Gianola, 1982). In regards to BRD, the prevalence of animals being infected is a small percentage of the overall population. Therefore, the majority of animals will be distributed in the healthy classification.

One of the first studies to express differences in which certain traits are expressed in the observed and unobserved scale involved guinea pigs. The number of digits guinea pigs had was seen as discontinuous on the observable scale, but was continuous on an unobservable scale (Wright, 1934). The idea of differences between two different scales (observable and unobservable) brought on new challenges to animal breeders. It is known that heritability is required to predict response to selection (Falconer and Mackay, 1996); therefore it is important that the transformation of the heritability estimate on the observed scale to underlying continuous scale is reasonable (Dempster and Lerner, 1950).

The linear model approach is used in the analysis of continuous traits as they use the assumption of normal distribution; however, this rule is violated with binary traits such as disease incidence as the phenotype distribution not normal and is inadequate to use for continuous traits (Gianola, 1982). For this same reason, threshold models have
been shown to be better and are well accepted for estimation of variance components for binary traits (Gianola, 1980; Gianola, 1982; Kadarmideen et al., 2000). Another advantage to using threshold models to analyze binary traits is that interactions on the underlying scale is expected to be less thus making fewer parameters needed compared to linear models (Kadarmideen et al., 2000). More problems that exist when analyzing binary traits are; that phenotype scores are arbitrarily assigned, which could lead to overestimation of heritability, mixed model methodology does not restrict the sum of probabilities which should not exceed 1, variance in observed scale varies and depends on the genotypic value of the animals in the population, the additive genetic variance relies on the mean incidence of the animal in the population being analyzed and nonadditive genetic variation is present in the observed scale (Gianola, 1980). With these reasons in mind non-linear models are used to analyze binary traits due to the problems that arise.
REFERENCE CITED


CHAPTER 3.

AN EVALUATION OF BOVINE RESPIRATORY INCIDENCE IN FEEDLOT CATTLE: I. IMPACT OF DISEASE ON PERFORMANCE AND CARCASS TRAITS USING TREATMENT RECORDS AND LUNG LESION SCORES\(^\dagger\)

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ABSTRACT: The objective of this study was to investigate the effects of bovine respiratory disease on economically important production traits with the use of health records in combination with lung lesion scores obtained at harvest. Records from 5,976 animals were utilized within this study from cattle that were managed in typical Midwestern feedlots. Average daily gain for three different time periods (warm-up period, on-test period, and overall test period) along with final weight were evaluated as performance measures. Hot carcass weight, rib-eye area, subcutaneous fat cover, and marbling score were collected at harvest. All calves were monitored by experienced feedlot personnel and treated according to each specific feedlot’s protocol. BRD incidence was observed at a rate of 8.17% and lung lesions at harvest were present in 61.9% of cattle from a sub population of 1,665 head. From this group of cattle the overall incidence of BRD, defined as cattle treated for BRD and/or cattle with lung lesions visible at the packing plant, was 64.4%. Treatment of BRD in the feedlot had a significant effect on both performance and carcass traits as evidenced by a reduction in ADG of 0.37 ± 0.03 kg / day during the warm-up period and a reduction of 0.07 ± 0.01 kg / day in overall ADG. Incidence of respiratory disease also had significant effects on hot carcass weight and marbling score with reduction in treated cattle of 8.16 ± 1.38 kg and 0.13 ± 0.04, respectively. The adverse effects on production traits tended to increase as the number of treatment increased. Potential decrease in performance and carcass merit observed in this study were associated with a decline of $23.23, $30.15, and $54.01 in carcass value when comparing cattle never treated to cattle treated once, twice, or three or more times, respectively. The presence of lung lesions did not have a significant effect
on any of the traits analyzed; however, there was an association between the presence of active bronchial lymph nodes and lower productivity of feedlot cattle.

**Key words:** bovine respiratory disease, cattle, lung lesion score, treatment records

**INTRODUCTION**

Bovine Respiratory Disease (BRD) is the biggest health obstacle the cattle industry faces due to the economic ramifications it presents. The economic cost associated with BRD has been reported to cost the industry $750 million per year (Griffin, 1997). The cost of one treatment has been estimated at $15.57 (Faber et al., 1999). This cost is amplified to $92.26 (McNeill et al., 1996) when indirect costs are also considered such as the reduction of average daily gain and lower carcass value due to less desirable quality grade.

BRD is commonly observed throughout the feedlot phase due to the stress factors that cattle face such as transportation, commingling from different sources, and feedlot processing. The incidence rate of clinical BRD was reported as 14.4% by USDA APHIS (2001), from a study of feedlots from 12 states in 1999. Lung lesions at harvest are extremely common with an observed prevalence ranging between 29.7% and 77% (Wittum et al., 1996; Bryant et al., 1999; Thompson et al., 2006) in feedlot cattle.

The first objective of this study was to examine the effects of BRD incidence and the frequency of treatments on economically important performance and carcass traits. The second objective was to examine the effect of lung lesion scores obtained at harvest as well as overall BRD which is the combination of BRD incidence and/or lung lesion presence at harvest on these same traits in feedlot cattle.
MATERIALS AND METHODS

The data analyzed within this study came from the Tri County Steer Carcass Futurity (TCSCF) test located in Southwest Iowa. Data included performance, carcass, health records and a portion of the cattle had lung lesion scores collected at harvest. This study utilized 5,976 head of cattle, which entered the feedlot between the years of 2003 to 2006. These cattle were consigned to TCSCF and were fed in 10 different feedlots. The fed cattle utilized in this study were originally from herds across the Midwest and Southeast U.S. In total 105 head (1.43%) died in the feedlot, in which 49% of deaths were attributed to BRD, 40% of deaths were due to reasons unrelated to BRD, and 11% of deaths were related to unknown causes.

Calves were processed on arrival to the Iowa feedlots where they were tagged, weighed, implanted, and vaccinated. Bulls or cattle with horns were omitted from the test. Cattle were fed a warm-up ration for a period of four to six weeks at which time on-test weight data was collected and cattle were started on an 80% concentrate ration. Carcass data were collected on harvested cattle at the packing plant by trained TCSCF personnel.

Health Management

Cattle were observed regularly by experienced feedlot personnel for any signs of sickness. Cattle were classified as having been treated for respiratory reasons when observed with symptoms consistent with BRD. Typical BRD symptoms include: breathing difficulty such as noisy or rapid breathing, coughing, decreased appetite, depression, droopy ears, eye discharge, fever, nasal discharge, open mouthed breathing,
and death. The specific health management for each feedlot was determined by the particular feedlot manager.

**Lung Lesion Scoring**

Cattle were harvested at a commercial packing plant (Tyson Foods, Denison, Iowa), where lungs were scored at chain speed as they passed by on a conveyor belt. Scoring was recorded and then matched to live identification at a later time. The lung lesion scoring system implemented in this study (D. Griffin, personal communication) consisted of slight modifications to procedures used by Bryant et al. (1999). Scoring was as follows; 0 = normal, no lesions observed, 1 = affected area involved less than one anterior ventral (A.V.) lobe and less than 5% lung volume, 2 = adhesions and/or affected area more than one A.V. lobe with greater than 5% but less than or equal to 10% of lung volume, 3 = adhesions affecting more than one A.V. lobe and/or greater than 10% to less than or equal to 15% lung volume affected and/or a small portion of lung missing, 4 = more than 15% missing lung volume, and 5= active bronchial lymph nodes. All scores were assigned by physical observations only; no physical handling of lungs was performed.

**Overall BRD**

Overall BRD incidence was defined as an animal that expressed symptoms of bovine respiratory disease and was treated, had lung lesions present at harvest, or a combination of both. This definition was used to evaluate animals that were thought to be truly affected by respiratory problems during the feedlot phase and to estimate the effects of overall BRD on performance and carcass traits.
Statistical Analysis

The GLM procedure of SAS (Version 9.1; SAS Inst. Inc., Cary, NC) was used to estimate the effects of BRD on performance and carcass traits. The number of records evaluated for each trait is listed in Tables 2 and 3. Performance traits analyzed included; warm-up ADG (early feeding period; initial 4 to 6 weeks), on-test ADG (late feeding period; end of warm-up period until harvest), overall ADG (total feedlot period), and final weight. Carcass traits consisted of hot carcass weight (HCW), rib-eye area (REA), subcutaneous fat cover (Fat), and marbling score (MarbS; 2.00 = Practically devoid, 3.00 = Traces, 4.00 = slight, 5.00 = small, 6.00 = Modest, 7.00 = Moderate, 8.00 = Slightly abundant, 9.00 = Moderately abundant, 10.00 = Abundant).

BRD incidence (BRD incidence) is defined as a binary classification of 0 for untreated and 1 for infected based on at least one feedlot treatment. The number of BRD (NoTrt) treatment was defined as the following: 0 if cattle were never treated for BRD, 1 if cattle were treated once for BRD, 2 if cattle were treated twice for BRD, and 3+ if cattle were treated three times or greater (thought to be suffering from chronic illness with BRD). Lesion presence (Lesion Presence) was measured as with or without (binary) the presence of lung lesions at harvest. Lung score (Lung Score) was measured as an ordinal variable associated with different levels of severity as previously described. Overall BRD was defined as the combination of BRD incidence and/or lung lesions observed at harvest time.

Analysis was completed for BRD incidence, number of BRD treatments, lesion presence, lung score, and overall BRD. The following model was used to estimate the effect of BRD on performance traits:
\[ y_{ijklm} = TRT_i + CG_j + Sex_k + DelWt_l + HD_m(CG_j) + \epsilon_{ijklm} \]

where \( y_{ijklm} \) = the trait measured on calf \( l \), in treatment \( i \), in contemporary group \( j \), of sex \( k \), and in harvest date \( m \); \( TRT_i \) = fixed effect of BRD Incidence \( i \), NoTrt \( i \), Lesion Presence \( i \), Lung Score \( i \), or Overall BRD \( i \); \( CG_j \) = fixed effect of contemporary group \( j \) (based on group of cattle that entered feedlot together and fed together through the feedlot phase); \( Sex_k \) = fixed effect of sex \( k \) (steer or heifer); \( DelWt_l \) = linear effect of the delivery weight of calf \( l \); \( HD_m(CG_j) \) = fixed effect of final harvest date \( m \) nested within contemporary group \( j \); \( \epsilon_{ijklm} \) = residual with \( \epsilon_{ijklm} \sim N(0, \sigma^2) \). For the analysis of carcass measures, similar fixed effects were fitted, however the linear effect of \( DelWt \) was replaced with the linear effect of age at harvest (AgeH).

**Economic Analysis**

An analysis was also conducted to evaluate the differences in monetary value in this study associated with the different BRD treatment classifications. All economic results are reported in the form of U.S. dollars. The first analysis was made on the actual income that cattle received. This income was figured by multiplying the hot carcass weight by the base carcass price with the addition of carcass premiums or discounts paid per head. The difference in value due directly to average daily gain and carcass quality grade were also investigated. The live price used in this study was determined by averaging the live price of cattle during the time period that cattle were harvested (USDA 2007b). The average price, $87.10 / cwt., was then multiplied by each calf’s overall average daily gain throughout the feedlot period, and then multiplied by days on feed. The differences in premiums or discounts paid for USDA Prime, Choice, Select and Standard quality grade were determined by averaging these values over this same time
period (USDA, 2007a). The value given to each USDA quality grade was as follows:
$8.35 / \text{cwt.}$ for Prime, $0.00 / \text{cwt.}$ for Choice, $-10.33 / \text{cwt.}$ for Select, and $-18.63 / \text{cwt.}$ for Standard. The differences in the quality grade were then multiplied by the hot carcass weight of each animal.

**RESULTS AND DISCUSSION**

In total 5,976 animals were utilized to analyze the effects of BRD incidence on performance and carcass traits, whereas the number of cattle with lung lesion data observed was 1,665. The majority of the cattle fed were steers, 4,791 head (80%), whereas heifers were represented by 1,185 head (20%). The average body weight upon entering the feedlot was 288 ± 44 kg, average age upon delivery was 287 ± 60 days, and mean on-test weight was 343 ± 49 kg. Mean warm-up ADG was 1.54 ± 0.69 kg / day, mean on-test ADG was 1.44 ± 0.29 kg / day, mean overall ADG was 1.46 ± 0.25 kg / day, and mean final weight was 539 ± 50 kg. The average HCW was 331 ± 32 kg, the mean REA was 80.90 ± 7.87 sq. cm., the mean fat was 11.18 ± 3.30 mm., and the mean marbling score was 5.30 ± 0.82.

Incidence rate of BRD in this study of feedlot cattle are presented in Table 1. BRD incidence totaled 8.17%, which is similar to the 8.7% reported in feedlots of similar size (USDA APHIS, 2001). A total of 488 head of cattle were treated for respiratory reasons; of which 53% were treated once, 34% were treated twice, and 13% were treated three times or more. The average day of first treatment was 40 days after entering the feedlot and 75% of treated cattle had been treated by day 55. This underlines the observation that first few weeks upon entering the feedlot is the most critical time period to observe feedlot cattle for BRD.
For lung lesion scoring, the lungs of 1,665 cattle were observed at harvest, with 61.9% of the lungs having lesions present. The percentage of cattle with lung lesions was similar to the results reported by Wittum et al. (1996) and Bryant et al. (1999), but higher than reported by Thompson et al. (2006). The distribution of lung lesion scores were as follows: 0 = 38.1%, 1 = 26.9%, 2 = 16.2%, 3 = 11.7%, 4 = 3.1%, and 5 = 4.0%. Lung lesions were found in 60.6% of cattle that were never treated for BRD, possibly indicating that feedlot observation simply missed a large number of cattle that suffered from BRD, many of these cattle suffered from subclinical disease, and/or that lesions observed were from instances of BRD exposure before arrival to the feedlot. Lesions were also observed in a majority of (74%) cattle that had been treated at least once. It is also important to note that treatment for BRD within these feedlots may not be completely effective in limiting the impact of disease or that some cases were severe enough to cause long term effects within the respiratory system. These results indicate that lung lesions are present not only in cattle with known infection of BRD, but also in cattle thought to be healthy and that a more accurate evaluation of BRD incident is determined with the use of both phenotypes. Also, a portion of treated animals (26%) did not have lung lesion present at harvest indicating that treatment for those cattle may have prevented any damage that infection may cause to the lungs.

Overall BRD in this study was defined as any animal treated for BRD and/or animal having lung lesions present at harvest. The estimated overall BRD incidence totaled 64.4% of cattle and may be a more accurate assessment of the true incidence of BRD in this population. This value is higher than the number of cattle treated for BRD (8.17%), but only slightly larger than cattle with lung lesions present at harvest (61.9%).
**Performance Traits**

Sources of variation for growth traits in feedlot cattle by BRD incidence, number of treatments, lung lesion presence, lung scores and overall BRD are presented in Table 2. Significant differences between treated and untreated cattle as well as the number of treatments were observed for warm-up ADG \((P < 0.01)\), overall ADG \((P < 0.01)\), and final weight \((P < 0.01)\); however, there was no significant impact on on-test ADG. Treatment for BRD was associated with a reduction of \(0.37 \pm 0.03\) kg/day in warm-up ADG (Table 4) and a reduction of \(0.07 \pm 0.01\) kg/day in overall ADG, indicating that cattle suffer the largest losses in performance during the early feeding period after entering the feedlot and some degree of subsequent compensatory gain is observed in treated cattle. The overall ADG reduction observed in this study is similar to the results reported by Bateman et al. (1990) and Gardner et al. (1999). The estimates among cattle in different treatment categories illustrate that as the number of treatments increased warm-up ADG (Figure 1), overall ADG (Figure 2), and final weight (Figure 3) decreased.

The analysis of lesion presence revealed no significant effects \((P > 0.05)\) on performance traits (Table 2). However, severity of lung scores had significant effects on on-test ADG \((P < 0.05)\), overall ADG \((P < 0.01)\), and final weight \((P < 0.01)\). In regard to on-test ADG, overall ADG, and final weight, there were no differences observed between lesion scores of 0, 1, 2, 3, or 4 \((P > 0.05)\), however when compared to lungs classified as a 5, which represents presence of active bronchial lymph nodes, significant differences \((P < 0.05)\) were detected (Figure 6, 7, and 8, respectively).
Carcass Traits

The significance of each fixed effect included in the model for carcass traits are listed in Table 3. Incidence of BRD and number of treatments described a significant amount of variation in hot carcass weight ($P < 0.01$), subcutaneous fat cover ($P < 0.01$), and marbling score ($P < 0.01$). Untreated cattle had more desirable estimates for all carcass traits when compared to treated cattle (Table 4). Specifically, a reduction of $8.16 \pm 1.38$ kg in hot carcass weight, $0.58 \pm 0.32$ sq. cm. for rib-eye area, $0.76 \pm 0.25$ mm. in fat cover, and $0.13 \pm 0.04$ in marbling score was observed in cattle treated for BRD. Similar results detected for performance traits were observed for hot carcass weight, and marbling score for the evaluation of treatment number (Figure 4 and 5). In addition, untreated cattle were fatter at harvest ($P < 0.01$) and tended to be heavier muscled ($P < 0.08$).

The distribution of quality grade among untreated cattle compared to the different treatment classifications are presented in Table 5. Greater than 71% of cattle never treated graded Choice category or better, while cattle treated once, twice, and three or more times graded Choice or higher only 57.69%, 55.15%, and 52.38%, respectively. Frequency differences were significant when comparing any of the treated categories with untreated cattle ($P < 0.05$). There were, however, no significant differences ($P > 0.05$) between the treated categories. These findings have important economic consequences due to the fact that there are considerable discounts paid for Select and Standard carcasses. When untreated cattle are compared to the chronically ill cattle that were treated at least three times, the frequency of cattle that fell within the Standard grade was five times higher. These results are similar to that of McNeil et al. (1996).
The presence of lung lesions at harvest did not have a significant ($P > 0.05$) impact on the carcass traits evaluated; however, lung scores had a significant effect on hot carcass weight ($P < 0.01$). Figure 9 illustrates the least square means for each lung score. Contrary to Gardner et al. (1999), lung score had no significant effect on marbling score. Differences between these two results could be due to the differences in the lung scoring systems implemented or the genetic background of the two different populations.

**Overall BRD**

When the incidence of BRD and the presence of lung lesions were combined we were able to examine the effects that overall BRD has on performance and carcass traits. Results for overall BRD are presented in Table 4. We observed that overall BRD significantly effected warm-up ADG ($P < 0.01$) with a difference of $0.07 \pm 0.03$ kg / day between treated and untreated cattle. It is possible that the difference in warm-up ADG was primarily due to the difference observed in treated cattle. Interestingly, overall BRD incidence had no significant effect on on-test or overall ADG. This indicates that when the combination of treatment and lung lesion are considered cattle were able to make-up losses in gain during the later feeding period, or some of the observed lung lesions may have resulted from causes other than BRD. Also of interest is that cattle falling within the overall BRD category of untreated tended to have heavier hot carcass weights ($P < 0.08$) and be heavier muscled ($P < 0.09$).

**Economics of BRD Treatment**

The differences in carcass value that this population of cattle brought to each producer when considering the carcass premiums and the actual price received are presented in Figure 10. When untreated cattle were compared to each BRD treatment
classification (1, 2, 3+), there was a difference of $23.23, $30.15, and $54.01 from untreated cattle, respectively. Cattle producers are interested in increasing profitability and cattle not suffering from BRD were more valuable in this study ($P < 0.01$).

Due to the fact that the value estimates above only reflects differences within a specific marketing scheme, an analysis of economic value due to performance and quality grade separately was conducted. Differences in value due to differences in ADG were $15.76, $22.09, and $46.70 when comparing cattle never treated for BRD with cattle in the 1, 2, and 3+ classifications, respectively. The decreased economic values attributed to differences in quality grade when compared to cattle never treated were $7.48, $9.58, and $7.70 for 1, 2, 3+ classification, respectively. These values underestimate total economic losses associated with BRD in this study as they do not account for the extra cost of treatment associated with medicine cost, labor, veterinarian fees, and death loss.

**Conclusion**

The results of this study indicate that BRD morbidity and the extent of treatment have major consequences on performance and carcass traits. Substantial per head losses in income were observed for cattle treated for BRD, which may be attributed to the effects of respiratory disease due to the combination of decreased lower performance and carcass quality.

In this study, the presence of lung lesions did not greatly influence any of the traits considered within this study, however the greatest loss of production is in cattle with active bronchial lymph nodes observed at harvest. This outcome is somewhat different than other reports on the effects of lung lesions on performance and carcass traits. Explanations why the results evaluated within this study differ could be due to a
couple of reasons, those being: 1. Lung lesions observed at harvest could be from infection prior to entering the feedlot, 2. The manner in which lungs were observed by the scorer was not sufficient to meet the criteria used in the lung scoring system implemented, and due to the lack of ability to physically manipulate lungs, there is considerable chance that lungs were misclassified.

Acknowledgements

I would like to thank the Tri County Steer Carcass Futurity (TCSCF) organization for allowing the use of their records in order to complete this research. We greatly appreciate everyone for being extremely helpful throughout this process. In addition, thank you to Dr. Dee Griffin from the USDA Meat Animal Research Center and Dr. Mike Wells from Pfizer for their willingness to train me on lung scoring. There is no doubt that this project would not be possible without everyone’s support.

LITERATURE CITED


Table 1. Distribution of bovine respiratory disease (BRD) incidence.

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<th>2004</th>
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<th>2006</th>
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<td>48</td>
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\(^a\)NoTrt = number of cattle treated for BRD; BRD incidence, % = no. treated / column total; total = no. of cattle.

\(^b\)Total is equal to the total of the preceding columns.
Table 2. Significance tests for fixed sources of variation for growth traits in feedlot cattle by type of BRD measurement used.

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<tr>
<td>On-test ADG</td>
<td>1,665</td>
<td>0.53</td>
<td>0.49</td>
<td>&lt; 0.01</td>
<td>&lt; 0.01</td>
<td>&lt; 0.01</td>
<td>&lt; 0.01</td>
</tr>
<tr>
<td>Overall ADG</td>
<td>1,665</td>
<td>0.53</td>
<td>0.52</td>
<td>&lt; 0.01</td>
<td>&lt; 0.01</td>
<td>&lt; 0.01</td>
<td>&lt; 0.01</td>
</tr>
<tr>
<td>Final Weight</td>
<td>1,665</td>
<td>0.61</td>
<td>0.39</td>
<td>&lt; 0.01</td>
<td>&lt; 0.01</td>
<td>&lt; 0.01</td>
<td>&lt; 0.01</td>
</tr>
</tbody>
</table>

*B*BRD Incidence = untreated (0) vs. treated (1), NoTrt is equal to; 0 = non treated cattle, 1 = cattle treated once, 2 = cattle treated twice, 3+ = cattle treated three or more times, Lesion presence = cattle with no lung lesions vs. cattle with lung lesions, Lesion score is equal to; 0 = Normal, no lesions observed, 1 = affected area involved less than one anterior ventral (A.V.) lobe and less than 5% lung volume, 2 = adhesions and/or affected area more than one A.V. lobe and less than 5% of lung volume, 3 = adhesions affecting more than one A.V. lobe and/or greater than 10% lung volume affected and/or a small portion of lung missing, 4 = more than 15% missing lung volume, and 5= active bronchial lymph nodes, Overall BRD is equal to cattle treated and/or cattle with lung lesions. Warm-up ADG = early feeding period, On-test ADG = late feeding period, Overall ADG = total feedlot period, and Final Weight = last weight before harvest.

*^b^TRT = BRD incidence, NoTrt, Lesion presence, Lesion score, and Overall BRD; CG = contemporary group; HD(CG) = final harvest date within contemporary group; Sex = steer or heifer, DelWt = weight upon delivery to feedlot.*
Table 3. Significance tests for fixed sources of variation for carcass traits in feedlot cattle by type of BRD measurement used.

<table>
<thead>
<tr>
<th>Itema</th>
<th>n</th>
<th>R²</th>
<th>TRT</th>
<th>CG</th>
<th>HD(CG)</th>
<th>Sex</th>
<th>AgeH</th>
</tr>
</thead>
<tbody>
<tr>
<td>BRD incidence</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>HCW</td>
<td>5,976</td>
<td>0.36</td>
<td>&lt; 0.01</td>
<td>&lt; 0.01</td>
<td>&lt; 0.01</td>
<td>&lt; 0.01</td>
<td>&lt; 0.01</td>
</tr>
<tr>
<td>REA</td>
<td>5,976</td>
<td>0.24</td>
<td>0.08</td>
<td>&lt; 0.01</td>
<td>&lt; 0.01</td>
<td>&lt; 0.01</td>
<td>&lt; 0.01</td>
</tr>
<tr>
<td>Fat</td>
<td>5,976</td>
<td>0.23</td>
<td>&lt; 0.01</td>
<td>&lt; 0.01</td>
<td>&lt; 0.01</td>
<td>&lt; 0.01</td>
<td>0.11</td>
</tr>
<tr>
<td>MarbS</td>
<td>5,976</td>
<td>0.30</td>
<td>&lt; 0.01</td>
<td>&lt; 0.01</td>
<td>&lt; 0.01</td>
<td>&lt; 0.01</td>
<td>&lt; 0.01</td>
</tr>
<tr>
<td>NoTrt</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>HCW</td>
<td>5,976</td>
<td>0.36</td>
<td>&lt; 0.01</td>
<td>&lt; 0.01</td>
<td>&lt; 0.01</td>
<td>&lt; 0.01</td>
<td>&lt; 0.01</td>
</tr>
<tr>
<td>REA</td>
<td>5,976</td>
<td>0.24</td>
<td>0.22</td>
<td>&lt; 0.01</td>
<td>&lt; 0.01</td>
<td>&lt; 0.01</td>
<td>&lt; 0.01</td>
</tr>
<tr>
<td>Fat</td>
<td>5,976</td>
<td>0.23</td>
<td>&lt; 0.01</td>
<td>&lt; 0.01</td>
<td>&lt; 0.01</td>
<td>&lt; 0.01</td>
<td>0.11</td>
</tr>
<tr>
<td>MarbS</td>
<td>5,976</td>
<td>0.30</td>
<td>&lt; 0.01</td>
<td>&lt; 0.01</td>
<td>&lt; 0.01</td>
<td>&lt; 0.01</td>
<td>&lt; 0.01</td>
</tr>
<tr>
<td>Lesion presence</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>HCW</td>
<td>1,665</td>
<td>0.36</td>
<td>0.26</td>
<td>&lt; 0.01</td>
<td>&lt; 0.01</td>
<td>&lt; 0.01</td>
<td>&lt; 0.01</td>
</tr>
<tr>
<td>REA</td>
<td>1,665</td>
<td>0.19</td>
<td>0.20</td>
<td>&lt; 0.01</td>
<td>0.19</td>
<td>&lt; 0.01</td>
<td>&lt; 0.01</td>
</tr>
<tr>
<td>Fat</td>
<td>1,665</td>
<td>0.20</td>
<td>0.39</td>
<td>&lt; 0.01</td>
<td>&lt; 0.01</td>
<td>&lt; 0.01</td>
<td>0.27</td>
</tr>
<tr>
<td>MarbS</td>
<td>1,665</td>
<td>0.28</td>
<td>0.94</td>
<td>&lt; 0.01</td>
<td>0.03</td>
<td>&lt; 0.01</td>
<td>&lt; 0.01</td>
</tr>
<tr>
<td>Lesion score</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>HCW</td>
<td>1,665</td>
<td>0.36</td>
<td>&lt; 0.01</td>
<td>&lt; 0.01</td>
<td>&lt; 0.01</td>
<td>&lt; 0.01</td>
<td>&lt; 0.01</td>
</tr>
<tr>
<td>REA</td>
<td>1,665</td>
<td>0.19</td>
<td>0.16</td>
<td>&lt; 0.01</td>
<td>0.16</td>
<td>&lt; 0.01</td>
<td>&lt; 0.01</td>
</tr>
<tr>
<td>Fat</td>
<td>1,665</td>
<td>0.20</td>
<td>0.14</td>
<td>&lt; 0.01</td>
<td>&lt; 0.01</td>
<td>&lt; 0.01</td>
<td>0.29</td>
</tr>
<tr>
<td>MarbS</td>
<td>1,665</td>
<td>0.28</td>
<td>0.64</td>
<td>&lt; 0.01</td>
<td>0.03</td>
<td>&lt; 0.01</td>
<td>&lt; 0.01</td>
</tr>
<tr>
<td>Overall BRD</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>HCW</td>
<td>1,665</td>
<td>0.36</td>
<td>0.08</td>
<td>&lt; 0.01</td>
<td>&lt; 0.01</td>
<td>&lt; 0.01</td>
<td>&lt; 0.01</td>
</tr>
<tr>
<td>REA</td>
<td>1,665</td>
<td>0.19</td>
<td>0.09</td>
<td>&lt; 0.01</td>
<td>0.18</td>
<td>&lt; 0.01</td>
<td>&lt; 0.01</td>
</tr>
<tr>
<td>Fat</td>
<td>1,665</td>
<td>0.20</td>
<td>0.25</td>
<td>&lt; 0.01</td>
<td>&lt; 0.01</td>
<td>&lt; 0.01</td>
<td>0.25</td>
</tr>
<tr>
<td>MarbS</td>
<td>1,665</td>
<td>0.28</td>
<td>0.93</td>
<td>&lt; 0.01</td>
<td>0.03</td>
<td>&lt; 0.01</td>
<td>&lt; 0.01</td>
</tr>
</tbody>
</table>

aBRD Incidence = untreated (0) vs. treated (1), NoTrt is equal to; 0 = non treated cattle, 1 = cattle treated once, 2 = cattle treated twice, 3 = cattle treated three or more times, Lesion presence = cattle with no lung lesions vs. cattle with lung lesions, Lesion score is equal to; 0 = Normal, no lesions observed, 1 = affected area involved less than one anterior ventral (A.V.) lobe and less than 5% lung volume, 2 = adhesions and/or affected area more than one A.V. lobe with greater than 5% of lung volume, 3 = adhesions affecting more than one A.V. lobe and/or greater than 10% lung volume affected and/or a small portion of lung missing, 4 = more than 15% missing lung volume, and 5= active bronchial lymph nodes, Overall BRD is equal to cattle treated and/or cattle with lung lesions. HCW = hot carcass weight, REA = rib-eye area, Fat = subcutaneous fat cover, and MarbS = marbling score.

bTRT = BRD incidence, NoTrt, Lesion presence, Lesion score, and Overall BRD; CG = contemporary group; HD(CG) = final harvest date within contemporary group; Sex = steer or heifer, Age = day age at harvest.
Table 4. Least square means results for performance and carcass traits where item was found to be significant.

<table>
<thead>
<tr>
<th>Itemᵃ</th>
<th>Untreated</th>
<th>SE</th>
<th>Treated</th>
<th>SE</th>
<th>Diffᵇ</th>
<th>SE</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>BRD incidence</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Warm-up ADG* kg/d</td>
<td>1.51</td>
<td>0.01</td>
<td>1.14</td>
<td>0.03</td>
<td>0.37</td>
<td>0.03</td>
</tr>
<tr>
<td>Overall ADG* kg/d</td>
<td>1.44</td>
<td>0.01</td>
<td>1.37</td>
<td>0.01</td>
<td>0.07</td>
<td>0.01</td>
</tr>
<tr>
<td>Final Weight* kg</td>
<td>531</td>
<td>0.90</td>
<td>520</td>
<td>1.75</td>
<td>11</td>
<td>1.65</td>
</tr>
<tr>
<td>HCW* kg</td>
<td>323</td>
<td>0.75</td>
<td>315</td>
<td>1.46</td>
<td>8.16</td>
<td>1.38</td>
</tr>
<tr>
<td>REA** sq cm</td>
<td>79.48</td>
<td>0.19</td>
<td>78.90</td>
<td>0.39</td>
<td>0.58</td>
<td>0.32</td>
</tr>
<tr>
<td>Fat* mm.</td>
<td>11.68</td>
<td>0.08</td>
<td>10.92</td>
<td>0.18</td>
<td>0.76</td>
<td>0.25</td>
</tr>
<tr>
<td>MarbS*ᵇ</td>
<td>5.38</td>
<td>0.02</td>
<td>5.25</td>
<td>0.04</td>
<td>0.13</td>
<td>0.04</td>
</tr>
<tr>
<td><strong>Overall BRD</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Warm-up ADG* kg/d</td>
<td>1.48</td>
<td>0.03</td>
<td>1.41</td>
<td>0.02</td>
<td>0.07</td>
<td>0.03</td>
</tr>
<tr>
<td>HCW** kg</td>
<td>330</td>
<td>1.68</td>
<td>327</td>
<td>1.39</td>
<td>3</td>
<td>1.73</td>
</tr>
<tr>
<td>REA** sq cm</td>
<td>81.42</td>
<td>0.39</td>
<td>80.77</td>
<td>0.32</td>
<td>0.65</td>
<td>0.39</td>
</tr>
</tbody>
</table>

ᵃBRD incidence = untreated (0) vs. treated (1), Overall BRD is equal to cattle treated and/or cattle with lung lesions. Warm-up ADG = early feeding period, On-test ADG = late feeding period, Overall ADG = total feedlot period, Final Weight = last weight before harvest, HCW = hot carcass weight, REA = rib-eye area, Fat = subcutaneous fat cover, and MarbS = marbling score.
ᵇ2.00 = Practically devoid⁰⁰; 3.00 = Traces⁰⁰; 4.00 = slight⁰⁰; 5.00 = small⁰⁰; 6.00 = Modest⁰⁰; 7.00 = Moderate⁰⁰; 8.00 = Slightly abundant⁰⁰; 9.00 = Moderately abundant⁰⁰; 10.00 = Abundant⁰⁰.
ᶜDiff = untreated minus treated.
* P-value = < 0.01 & ** P-value = < 0.10
**Table 5.** The percentage of carcass quality grade by the number of bovine respiratory disease treatment category.

<table>
<thead>
<tr>
<th>USDA Quality Grade</th>
<th>0&lt;sup&gt;b&lt;/sup&gt;</th>
<th>1</th>
<th>2</th>
<th>3+</th>
</tr>
</thead>
<tbody>
<tr>
<td>Prime</td>
<td>0.89</td>
<td>0</td>
<td>1.82</td>
<td>1.59</td>
</tr>
<tr>
<td>Choice</td>
<td>70.15</td>
<td>57.69</td>
<td>53.33</td>
<td>50.79</td>
</tr>
<tr>
<td>Select</td>
<td>27.41</td>
<td>39.62</td>
<td>41.82</td>
<td>39.68</td>
</tr>
<tr>
<td>Standard</td>
<td>1.55</td>
<td>2.69</td>
<td>3.03</td>
<td>7.94</td>
</tr>
</tbody>
</table>

<sup>a</sup>0 = non treated cattle, 1 = cattle treated once, 2 = cattle treated twice, 3+ = cattle treated three or more times.

<sup>b</sup>Cattle never treated are significantly different ($P < 0.05$) than cattle treated 1, 2, 3+. There was no significant difference ($P > 0.05$) between cattle treated 1, 2, or 3+. 
Figure 1. LS means estimates for warm-up average daily gain between the number of treatment classification for bovine respiratory disease (BRD).

Warm-Up ADG

ADG, kg/day

BRD Treatment Classification\textsuperscript{a}

\begin{itemize}
  \item 0 = non treated cattle
  \item 1 = cattle treated once
  \item 2 = cattle treated twice
  \item 3+ = cattle treated three or more times
\end{itemize}

\textsuperscript{a}LS means with different letters are statistically different ($P < 0.10$)
**Figure 2.** LS means estimates for overall average daily gain between the number of treatment classification for bovine respiratory disease (BRD).

*Overall ADG*

<table>
<thead>
<tr>
<th>ADG kg/day</th>
<th>0.00</th>
<th>0.05</th>
<th>0.10</th>
<th>0.15</th>
<th>0.20</th>
<th>0.25</th>
<th>0.30</th>
<th>0.35</th>
<th>0.40</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>b</td>
<td>c</td>
<td>c</td>
<td>d</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

$^a$0 = non treated cattle, 1 = cattle treated once, 2 = cattle treated twice, 3+ = cattle treated three or more times

$^b$LS means with different letters are statistically different ($P < 0.10$)
**Figure 3.** LS means estimates for final weight between the number of treatment classification for bovine respiratory disease (BRD).

Final Weight

<table>
<thead>
<tr>
<th>BRD Treatment Classification&lt;sup&gt;a&lt;/sup&gt;</th>
<th>Final Weight (kg)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>b</td>
</tr>
<tr>
<td>1</td>
<td>c</td>
</tr>
<tr>
<td>2</td>
<td>c</td>
</tr>
<tr>
<td>3+</td>
<td>d</td>
</tr>
</tbody>
</table>

<sup>a</sup>0 = non treated cattle, 1 = cattle treated once, 2 = cattle treated twice, 3+ = cattle treated three or more times

<sup>b</sup>c<sup>d</sup> LS means with different letters are statistically different (<i>P < 0.10</i>)
Figure 4. LS means estimates for hot carcass weight between the number of treatment classification for bovine respiratory disease (BRD).

HCW

![Bar chart showing hot carcass weight (HCW) by BRD treatment classification.](image)

a0 = non treated cattle, 1 = cattle treated once, 2 = cattle treated twice, 3+ = cattle treated three or more times

bcd LS means with different letters are statistically different ($P < 0.10$)
Figure 5. LS means estimates for marbling score between the number of treatment classification for bovine respiratory disease (BRD).

Marbling Score

BRD Treatment Classification*a

0 = non treated cattle, 1 = cattle treated once, 2 = cattle treated twice, 3+ = cattle treated three or more times

Marbling Score b

2.00 = Practically devoid00; 3.00 = Traces00; 4.00 = slight00; 5.00 = small00; 6.00 = Modest00; 7.00 = Moderate00; 8.00 = Slightly abundant00; 9.00 = Moderately abundant00; 10.00 = Abundant00.

c,d LS means with different letters are statistically different (P < 0.10)
**Figure 6.** LS means estimates for on-test ADG based on lung lesion score.

![Bar chart showing ADG kg/day vs Lung Lesion Score](chart.png)

- **LS means estimates for on-test ADG based on lung lesion score.**

<table>
<thead>
<tr>
<th>Lung Lesion Score</th>
<th>ADG kg/day</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>b</td>
</tr>
<tr>
<td>1</td>
<td>b</td>
</tr>
<tr>
<td>2</td>
<td>b</td>
</tr>
<tr>
<td>3</td>
<td>b</td>
</tr>
<tr>
<td>4</td>
<td>b</td>
</tr>
<tr>
<td>5</td>
<td>c</td>
</tr>
</tbody>
</table>

**Notes:**
- 0 = Normal, no lesions observed, 1 = affected area involved less than one anterior ventral (A.V.) lobe and less than 5% lung volume, 2 = adhesions and/or affected area more than one A.V. lobe with greater than 5% of lung volume, 3 = adhesions affecting more than one A.V. lobe and/or greater than 10% lung volume affected and/or a small portion of lung missing, 4 = more than 15% missing lung volume, and 5 = active bronchial lymph nodes.
- LS means with different letters are statistically different ($P < 0.10$)
**Figure 7.** LS means estimates for overall ADG bases on lung lesion score.

Overall ADG

- **ADG kg / day**
  - 1.20
  - 1.25
  - 1.30
  - 1.35
  - 1.40
  - 1.45

Lung Lesion Score

- **a0 = Normal, no lesions observed, 1 = affected area involved less than one anterior ventral (A.V.) lobe and less than 5% lung volume, 2 = adhesions and/or affected area more than one A.V. lobe with greater than 5% of lung volume, 3 = adhesions affecting more than one A.V. lobe and/or greater than 10% lung volume affected and/or a small portion of lung missing, 4 = more than 15% missing lung volume, and 5= active bronchial lymph nodes.**

- **bc** LS means with different letters are statistically different ($P < 0.10$)
**Figure 8.** LS means estimates for final weight based on lung lesion score.

Final Weight

\[ \text{Final Weight} \]

$0 = \text{Normal, no lesions observed, } 1 = \text{affected area involved less than one anterior ventral (A.V.) lobe and less than 5% lung volume, } 2 = \text{adhesions and/or affected area more than one A.V. lobe with greater than 5% of lung volume, } 3 = \text{adhesions affecting more than one A.V. lobe and/or greater than 10% lung volume affected and/or a small portion of lung missing, } 4 = \text{more than 15% missing lung volume, and } 5 = \text{active bronchial lymph nodes.} \]

$\text{b}_c \text{LS means with different letters are statistically different } (P < 0.10)$
Figure 9. LS means estimates for hot carcass weight based on lung lesion score.

*a0 = Normal, no lesions observed, 1 = affected area involved less than one anterior ventral (A.V.) lobe and less than 5% lung volume, 2 = adhesions and/or affected area more than one A.V. lobe with greater than 5% of lung volume, 3 = adhesions affecting more than one A.V. lobe and/or greater than 10% lung volume affected and/or a small portion of lung missing, 4 = more than 15% missing lung volume, and 5 = active bronchial lymph nodes.

*bcLS means with different letters are statistically different ($P < 0.10$)
**Figure 10.** LS means estimates for actual cattle gross income.

Cattle Income

<table>
<thead>
<tr>
<th>BRD Treatment Classification</th>
<th>Cattle Value, $</th>
</tr>
</thead>
<tbody>
<tr>
<td>0 (non treated)</td>
<td>1010</td>
</tr>
<tr>
<td>1 (cattle treated once)</td>
<td>990</td>
</tr>
<tr>
<td>2 (cattle treated twice)</td>
<td>970</td>
</tr>
<tr>
<td>3+ (cattle treated three or more times)</td>
<td>950</td>
</tr>
</tbody>
</table>

\[ a \] 0 = non treated cattle, 1 = cattle treated once, 2 = cattle treated twice, 3+ = cattle treated three or more times

\[ bcd \] LS means with different letters are statistically different \((P < 0.10)\)
CHAPTER 4.

AN EVALUATION OF BOVINE RESPIRATORY INCIDENCE IN FEEDLOT CATTLE: II. FIXED SOURCES OF VARIATION AND GENETIC PARAMETERS

A paper to be submitted to the Journal of Animal Science

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ABSTRACT: The primary objective of this study was to estimate variance components and heritability of bovine respiratory disease (BRD) incidence during the finishing phase of cattle fed in typical Midwest feedlots within the U.S. cattle industry. The second objective was to investigate the impact of BRD incidence and treatment frequency on performance and carcass traits. Bovine respiratory disease is the one of the biggest health challenge facing the cattle industry and there are great economic consequences associated with BRD. This study used records from 3,138 head of Angus sired cattle from Midwestern feedlots with a BRD incidence rate of 8.32%. The incidence of BRD had significant ($P < 0.05$) negative effects on overall average daily gain with a reduction of $0.06 \pm 0.01$ kg/d, and particularly during the early time period after cattle arrived to the feedlot with an average daily gain reduction of $0.45 \pm 0.04$ kg/d associated with BRD stricken cattle. Carcass traits were also significantly ($P < 0.05$) affected by BRD incidence as untreated cattle had a $9.07 \pm 1.77$ kg advantage in hot carcass weight and an increase in marbling score of $0.12 \pm 0.05$. Similar results were observed in the analysis of treatment frequency. The heritability estimate of BRD incidence was $0.07 \pm 0.04$, while the heritability of the number of treatments for respiratory reasons was $0.05 \pm 0.04$. Estimates of genetic correlations of BRD incidence with other production measures were: $-0.90 \pm 0.20$ for warm-up ADG, $0.14 \pm 0.25$ for on-test ADG, $-0.35 \pm 0.22$ for overall ADG, $-0.43 \pm 0.21$ for final weight, $0.00 \pm 0.23$ for HCW, $0.02 \pm 0.23$ for REA, $-0.03 \pm 0.26$ for fat, and $-0.42 \pm 0.21$ for marbling score. The genetic correlation between the number of treatments and production measures were: $-0.94 \pm 0.21$ for warm-up ADG, $0.18 \pm 0.30$ for on-test ADG, $-0.40 \pm 0.25$ for overall ADG, $-0.55 \pm 0.24$ for final weight, $-0.21 \pm 0.27$ for HCW, $-0.03 \pm 0.27$ for REA, $0.00 \pm 0.31$ for fat, and $-0.32 \pm 0.26$ for marbling score. Detrimental effects on important production traits due to BRD were also observed.
Though the heritability estimates were low, breeding programs designed for the selection of reduced BRD incidence may be possible and certainly are of great interest to the cattle industry.

**Key words:** bovine respiratory disease, cattle, disease resistance, genetics

**INTRODUCTION**

Bovine respiratory disease is the most prevalent and economically devastating health concern to the cattle industry (USDA NAHMS, 2000). The overall cost to the industry has been estimated as $750 million per year (Griffin, 1997). Cattle entering the feedlot are at a high risk of contracting BRD due to the stress of transportation and commingling among many different sources with differing health backgrounds. A single treatment for BRD has been estimated to cost $15.57 (Faber et al., 1999) due to expenses related to pharmaceutical products and supplies, whereas total associated costs of BRD treatment as it relates to loss of production and lower carcass value has been reported at $92.26 (McNeill et al., 1996).

In feedlot cattle, incidence rate of BRD has been reported at 14.4% (USDA NAHMS, 2000), and lung lesions prevalent at harvest has been observed between 29.7% and 77% (Wittum et al., 1996; Bryant et al., 1999; Thompson et al., 2006). Bovine respiratory disease is a growing concern as disease incidence has been increasing (Babcook et al., 2006), while corresponding deaths of infected cattle have increased from 52.1% in 1994 to 61.5% in 1999 (USDA NAHMS, 2000).

Heritability estimates of BRD resistance have previously been estimated in pre-wean calves by Muggli-Cockett et al. (1992) ($h^2 = 0.10$), and Snowder et al. (2005) ($h^2 = 0.00$ to 0.26). In feedlot cattle, Snowder et al. (2006) estimated heritability of BRD resistance between 0.04 and 0.08, with an estimate of the underlying continuous scale of 0.18. The
primary objective of this study was to estimate variance components and the associated heritability of BRD incidence during the finishing phase using health records of feedlot cattle fed in a typical feedlot environment. The second objective was to investigate the impact of BRD incidence and treatment frequency on performance and carcass traits.

**MATERIALS AND METHODS**

The data analyzed within this study were obtained from 3,138 head of cattle with known Angus sires as described in Schneider et al. (Chapter 3). Performance, carcass, sire registration numbers and health records were obtained from the Tri County Steer Carcass Futurity (TCSCF). This organization is designed to relay information regarding the performance, carcass, and economics components of retained ownership back to the cow/calf consignors for use as decisions tools in their operation.

**Health Management**

The health protocols in place are determined by each particular feedlot; however, guidelines established by the TCSCF organization ensure that optimal health standards are applied to each feedlot setting. Clinical symptoms common with BRD are fever, breathing difficulty, coughing, nasal and eye discharge, droopy ears, lethargic cattle and decreased appetite. Health records from each feedlot were examined to establish disease classifications of diagnosis for each treated animal. Diagnosis of BRD can be complicated due to the wide range of symptoms as well as the difficulties of distinguishing between other diseases. Thus, guidelines used in this study for defined BRD treatment are representative of typical standards used by feedlot managers across the cattle industry.
Statistical Analysis

The same procedures used in Schneider et al. (Chapter 3) were utilized with this study to determine the final model for analysis. Records from cattle that either died during the feedlot period or were missing values for the traits of interest were eliminated from the final data set (n = 3,138). The binary classification for respiratory treatment was defined as either treated (BRD Incidence = 1) or untreated (BRD Incidence = 0). For the analysis of number of treatments (NoTrt), animals were classified as 0 for untreated cattle, 1 for cattle treated once, 2 for cattle treated twice, and 3+ for animals treated three or more times (indicating cattle chronically ill with respiratory problems).

The models used to estimate the effect of BRD on warm-up ADG (early feeding period; initial 4 to 6 weeks), on-test ADG (late feeding period; end of warm-up period until harvest), overall ADG (total feedlot period), and final weight as well as hot carcass weight, rib-eye area, subcutaneous fat cover, and marbling score (2.00 = Practically devoid; 3.00 = Traces; 4.00 = slight; 5.00 = small; 6.00 = Moderate; 7.00 = Moderate; 8.00 = Slightly abundant; 9.00 = Moderately abundant; 10.00 = Abundant) was the same as the models described in Schneider et al. (Chapter 3). The final analysis model was developed using Proc GLM of SAS (Version 9.1; SAS Inst. Inc., Cary, NC), and was as follows:

\[ y_{ijklm} = \text{TRTi} + \text{CGj} + \text{Sexk} + \text{DelWtl} + \text{HDm(CGj)} + \varepsilon_{ijklm} \]

where \( y_{ijklm} \) = the trait measured on calf \( l \), in treatment \( i \), in contemporary group \( j \), of sex \( k \), and in harvest date \( m \); \( \text{TRTi} \) = fixed effect of BRD Incidence \( i \) or NoTrt \( i \); \( \text{CGj} \) = fixed effect of contemporary group \( j \) (based on group of cattle that entered feedlot together and fed together through the feedlot phase); \( \text{Sexk} \) = fixed effect of sex \( k \) (steer or heifer); \( \text{DelWtl} \) = linear effect of the delivery weight of calf \( l \); \( \text{HDm(CGj)} \) = fixed effect of final harvest date \( m \).
nested within contemporary group \( j \); \( \varepsilon_{ijklm} = \) residual with \( \varepsilon_{ijklm} \sim N(0, \sigma_e^2) \). The above model was used for the analysis of all performance traits. For the analysis of carcass measures, similar fixed effects were fitted, however the linear effect of DelWt was replaced with the linear effect of age at harvest (AgeH).

Genetic parameters were estimated using a sire model within MTDFREML (Boldman et al. 1995). A three generation sire pedigree was constructed from data provided by the American Angus Association. In total, there were 956 animals within the pedigree file and encompassed 421 different sires with direct progeny in the feedlot. The pedigree included 261 inbred animals with an average inbreeding coefficient of 1.76%. The model used within MTDFREML for each trait was as follows: \( y = Xb + Za + e \), where \( y = \) vector of observations; \( b = \) vector of fixed effects, \( a = \) vector of random additive sire effects, which utilizes the numerator relationship matrix among sires; \( e = \) vector of residuals. The incidence matrices relating observations to fixed effects and random animal are \( X \) and \( Z \), respectively. Fixed effects included in the analysis of BRD incidence and number of treatments was contemporary group (based on group of cattle that entered feedlot together and fed together through the feedlot phase) along with a linear covariate of individual delivery weight. Similar fixed effects were included in the analysis of performance traits with the addition of sex within the model of warm-up ADG, whereas sex and harvest date within contemporary group was added to the analysis of on-test ADG, overall ADG, and final weight. Fixed effects included in the analysis of hot carcass weight, rib-eye area, subcutaneous fat cover, and marbling score was contemporary group, sex, harvest date within contemporary group, and a linear covariate of individual age at harvest.
Convergence was defined when the variance of simplex of -2 logL was less than \(1 \times 10^{-9}\). After initial convergence was attained, three restarts were performed to ensure global convergence. For single trait models, variance component estimates were used to calculate heritability as the ratio of: \((4 \times V_A) / V_P\) (Falconer and Mackay, 1996). Bivariate models were utilized to estimate genetic correlations for BRD with performance and carcass traits. Phenotypic correlations were calculated as the ratio of phenotypic covariance estimates to the product of respective phenotypic standard deviation estimates.

**RESULTS AND DISCUSSION**

Mean delivery weight to the feedlot for this population was 286 ± 42 kg and mean on-test weight was 343 ± 48 kg. Warm-up, on-test, and overall ADG averaged 1.57 ± 0.59, 1.47 ± 0.29, and 1.48 ± 0.23 kg/day respectively. A higher ADG for the warm-up period may be explained by the fact that initial weight included within the calculation is greatly affected by shrinking related to transportation. The average age upon delivery was 290 ± 56 days, and mean final weight was 536 ± 47 kg. The average HCW was 329 ± 30 kg, the mean REA was 79.74 ± 6.65 sq. cm., the mean fat was 11.94 ± 3.30 mm., and the mean marbling score was 5.53 ± 0.87.

**Performance Traits**

The average incidence of BRD across all years was 8.32% with 261 animals were treated at least once (Table 1). Among treated cattle, 49.8% were treated once, 36.4% were treated twice and 13.8% were treated three times or more. In total, 55 head (1.62%) of cattle died during the feeding phase, 56.4% of which were attributed to respiratory reasons. The BRD incidence rate observed in this study is within the lower range of previous reports of 5 to 50% (Gardner et al. 1999; Snowder et al. 2006), and could be attributed to the high
management standards and pre-delivery protocols in place, or may indicate that the exposure to pathogens associated with BRD was minimal in the present study.

Sources of variation for BRD incidence and number of treatments on measures of feedlot performance traits are presented in Table 2. The effects of clinical BRD on cattle performance were similar to the results reported in Schneider et al. (Chapter 3). Least square means estimates for production traits that BRD incidence had a significant effect on are presented in Table 4. Feedlot cattle diagnosed with BRD had significantly \( (P < 0.01) \) lower ADG during the warm-up period \( (1.10 \pm 0.04 \text{ vs. } 1.55 \pm 0.02 \text{ kg/d}) \); however, no significant effect was observed on ADG during the on-test period \( (P < 0.92) \). The length of the warm-up period averaged 37 days in the current study. This time period represents the most critical period, as a majority of BRD incidence occurred during or directly after this time period within the population under study. Overall ADG was adversely affected \( (P < 0.01) \) by treatment for BRD as treated cattle gained \( 0.06 \pm 0.01 \text{ kg/day} \) less when compared to untreated cattle. These results indicate that BRD incidence has a detrimental effect on ADG, especially early in the finishing period. In addition, due to the fact that cattle treated for BRD have a much lower effect on ADG when considering the entire feedlot phase compared to the warm-up period, perhaps cattle properly treated for BRD are able to closer match the performance of untreated after the effect of infection have been minimized.

Number of treatments revealed similar results to the analysis of BRD incidence, as significant effects on both warm-up ADG \( (P < 0.01) \) and overall ADG \( (P < 0.01) \) were observed for treatment numbers. As expected, cattle that were never treated had higher estimates for ADG for both time periods. Cattle treated once or twice did not differ
significantly for warm-up ADG \((P < 0.19)\) or overall ADG \((P < 0.77)\), but were significantly different than cattle treated three times or more \((P < 0.10)\).

**Carcass Traits**

The effect of BRD incidence and NoTrt on carcass traits are presented in Table 3. Carcasses from cattle treated had lighter hot carcass weights by \(9.07 \pm 1.77\) kg \((P < 0.01)\) when compared to healthy cattle (Table 4). This result may be explained by the effect of BRD incidence on average daily gain, which subsequently leads to lighter final live weights at a constant age. Treated cattle were also leaner \((11.43 \pm 0.25\) mm vs. \(12.19 \pm 0.25\) mm; \(P < 0.01)\) and had lower marbling scores \((5.48 \pm 0.06, \text{small48 vs. } 5.60 \pm 0.03, \text{small60}; P < 0.03)\). The distribution of USDA quality grades assigned to carcasses illustrated that approximately 81% of cattle never treated for BRD received the Choice category or better (Table 5), which is slightly higher than what was reported by Schneider et al. (Chapter 3). This is a definite advantage when compared to cattle in the other treatment categories (1 = 71.54%, 2 = 70.53%, 3+ = 72.22%). When marketing under value based systems, this result may have a profound effect on the profit potential to feedlots. The effect of number of treatments on hot carcass weight, subcutaneous fat cover, and marbling score were generally similar to those reported by Schneider et al. (Chapter 3). With regards to each trait, the values associated with hot carcass weight, subcutaneous fat cover, and marbling score decreased as the number of treatments increased.

**Genetic Parameters**

Estimates from single trait analysis of respiratory disease, performance, and carcass traits are presented in Table 6. The heritability estimate for BRD incidence was \(0.07 \pm 0.04\), which was similar to the reports of Snowder et al. (2006) and Snowder et al. (2007) \((h^2 =\)
Analysis of number of treatment for BRD revealed a heritability estimate of 0.05 ± 0.04. The results of this study agree with conclusions of Snowder et al. (2006), in that developing a selection program with an emphasis on BRD resistance is possible. The heritability of BRD incidence estimated within this study was observed with a disease rate of 8.32%, which is approaching the lower end of the incidence expectation, and there is evidence that as incidence rate is increased heritability estimates are increased (Snowder et al., 2006).

Heritability estimates for all production traits were moderate to high (Table 6). Estimates for performance traits ranged from 0.55 to 0.71 and carcass traits ranged from 0.34 to 0.73. In comparison to the heritability estimates from the American Angus Association for carcass weight (0.30), fat thickness (0.25), rib-eye area (0.28), and marbling score (0.36) the estimated heritability estimates from this study are higher. It is believed that this is the result of the consistent manner in which all cattle are fed and managed by the TCSCF organization. The selection of breeding stock used by cattle producers within this management system is extremely important and the potential to increase production due to genetics would be beneficial.

Phenotypic and genetic correlations were estimated among BRD incidence or number of BRD treatments with all performance and carcass traits evaluated within this study (Table 7). Phenotypic correlations between all production traits with BRD incidence and number of BRD treatments were lowly correlated and ranged between -0.05 and 0.01. Moderate to high estimates of genetic correlations were estimated between BRD incidence and warm-up ADG (-0.90 ± 0.20), overall ADG (-0.35 ± 0.22), and final weight (-0.43 ± 0.21). However, the genetic relationship of BRD incidence and on-test ADG was 0.14
± 0.25. Similar genetic relationships were estimated between the number of BRD treatments and the above performance traits (Table 7). The only known estimates of genetic correlation of BRD incidence is with ADG from the entire feedlot phase of 0.08 ± 0.07 (Snowder et al., 2007). When considering the SE for the estimate of genetic correlation for BRD incidence with overall ADG, the results from this study are similar.

Genetic correlations between either health measure were similar when carcass traits were analyzed (Table 7). Hot carcass weight, rib-eye area, and subcutaneous fat cover ranged from -0.03 to 0.02 for BRD incidence and -0.21 to 0.00 for treatment numbers. The estimate for genetic correlations with BRD incidence and number of treatments with marbling score were -0.42 ± 0.21 and -0.32 ± 0.26, respectively. This is a much more favorable genetic correlation of BRD incidence with marbling score than Snowder et al. (2007) reported (0.09 ± 0.13).

Further investigations in regards to heritability estimates and genetic correlations were completed using two different bivariate analyses. The first method included BRD incidence as a fixed effect within the model for each production trait, where as the second procedure was similar with the addition of fixing BRD incidence heritability from estimates obtained by the single trait analysis. The reasoning behind this step was to determine the effect that inclusion of BRD incidence within the model might have on the accuracy of estimating variance components. Both of these two procedures showed similar results, and neither changed heritability estimates from what is reported in this study (Data not shown).

**Conclusion**

This study utilized field data from typical Midwest feedlots and the results indicate that the incidence of BRD has negative effects on important performance and carcass traits
as well as the number of times cattle are treated has adverse effects. Though the heritability estimate for BRD was low, results here illustrate that breeding schemes could be developed to incorporate BRD resistance into selection schemes for improved cattle health to ultimately increase profit potential. In addition, this study indicates that selection for BRD resistance may have little effect on hot carcass weight, rib-eye area, and subcutaneous fat cover due to the low correlation estimates especially when considering the large SE. Strong high favorable genetic correlations exist for average daily gain, final weight, and marbling score with either health measure. Selection for reduced BRD incidence could be beneficial not only in terms of lower disease incidence but also in regards to increasing performance and carcass quality from a genetic merit perspective.

Acknowledgements

I would like to thank the Tri County Steer Carcass Futurity (TCSCF) organization for their helpfulness throughout this process. We greatly appreciate the data we were able to use and this project would not have been possible without your support.

LITERATURE CITED


Table 1. The distribution of bovine respiratory disease (BRD) incidence by year.

<table>
<thead>
<tr>
<th>Item</th>
<th>Year entered feedlot</th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>2003</td>
<td>2004</td>
<td>2005</td>
<td>2006</td>
<td>Overall&lt;sup&gt;b&lt;/sup&gt;</td>
</tr>
<tr>
<td>NoTrt</td>
<td>95</td>
<td>28</td>
<td>94</td>
<td>44</td>
<td>261</td>
</tr>
<tr>
<td>BRD incidence, %</td>
<td>13.67</td>
<td>3.67</td>
<td>8.94</td>
<td>7.27</td>
<td>8.32</td>
</tr>
<tr>
<td>Total</td>
<td>719</td>
<td>762</td>
<td>1,052</td>
<td>605</td>
<td>3,138</td>
</tr>
</tbody>
</table>

<sup>a</sup>NoTrt = number of cattle treated for BRD; BRD incidence = no. treated / column total; total = number of cattle within year.

<sup>b</sup>Overall equals the total number of cattle treated across years.
Table 2. Significance tests for fixed sources of variation for growth traits in feedlot cattle by type of BRD measurement used.

<table>
<thead>
<tr>
<th>Item&lt;sup&gt;a&lt;/sup&gt;</th>
<th>n</th>
<th>R²</th>
<th>TRT</th>
<th>CG</th>
<th>HD(CG)</th>
<th>Sex</th>
<th>DelWt</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>BRD incidence</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Warm-up ADG</td>
<td>3,027</td>
<td>0.47</td>
<td>&lt; 0.01</td>
<td>&lt; 0.01</td>
<td>&lt; 0.01</td>
<td>0.07</td>
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</tr>
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<td>On-test ADG</td>
<td>3,138</td>
<td>0.50</td>
<td>0.92</td>
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<td>&lt; 0.01</td>
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<td>&lt; 0.01</td>
</tr>
<tr>
<td>Overall ADG</td>
<td>3,138</td>
<td>0.46</td>
<td>&lt; 0.01</td>
<td>&lt; 0.01</td>
<td>&lt; 0.01</td>
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</tr>
<tr>
<td>Final Weight</td>
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<td>0.62</td>
<td>&lt; 0.01</td>
<td>&lt; 0.01</td>
<td>&lt; 0.01</td>
<td>&lt; 0.01</td>
<td>&lt; 0.01</td>
</tr>
<tr>
<td><strong>NoTrt</strong></td>
<td></td>
<td></td>
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<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Warm-up ADG</td>
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<td>0.66</td>
<td>&lt; 0.01</td>
<td>&lt; 0.01</td>
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</tr>
<tr>
<td>Overall ADG</td>
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<td>0.46</td>
<td>&lt; 0.01</td>
<td>&lt; 0.01</td>
<td>&lt; 0.01</td>
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<tr>
<td>Final Weight</td>
<td>3,138</td>
<td>0.62</td>
<td>&lt; 0.01</td>
<td>&lt; 0.01</td>
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</table>

<sup>a</sup>BRD Incidence = untreated (0) vs. treated (1), NoTrt is equal to; 0 = non treated cattle, 1 = cattle treated once, 2 = cattle treated twice, 3+ = cattle treated three or more times. Warm-up ADG = early feeding period, On-test ADG = late feeding period, Overall ADG = total feedlot period, and Final Weight = last weight before harvest.

<sup>b</sup>TRT = BRD incidence or NoTrt; CG = contemporary group; HD(CG) = final harvest date within contemporary group; Sex = steer or heifer, DelWt = weight upon delivery to feedlot.
Table 3. Significance tests for fixed sources of variation for carcass traits in feedlot cattle by type of BRD measurement used.

<table>
<thead>
<tr>
<th>Item(^a)</th>
<th>n</th>
<th>R(^2)</th>
<th>TRT</th>
<th>CG</th>
<th>HD(CG)</th>
<th>Sex</th>
<th>AgeH</th>
</tr>
</thead>
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<tr>
<td><strong>BRD incidence</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>HCW</td>
<td>3,138</td>
<td>0.36</td>
<td>&lt; 0.01</td>
<td>&lt; 0.01</td>
<td>&lt; 0.01</td>
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<tr>
<td>REA</td>
<td>3,138</td>
<td>0.24</td>
<td>0.30</td>
<td>&lt; 0.01</td>
<td>&lt; 0.01</td>
<td>&lt; 0.01</td>
<td>&lt; 0.01</td>
</tr>
<tr>
<td>Fat</td>
<td>3,138</td>
<td>0.24</td>
<td>&lt; 0.01</td>
<td>&lt; 0.01</td>
<td>&lt; 0.01</td>
<td>&lt; 0.01</td>
<td>0.03</td>
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<tr>
<td>MarbS</td>
<td>3,138</td>
<td>0.32</td>
<td>0.03</td>
<td>&lt; 0.01</td>
<td>&lt; 0.01</td>
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<tr>
<td><strong>NoTrt</strong></td>
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<tr>
<td>HCW</td>
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<td>0.36</td>
<td>&lt; 0.01</td>
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<td>REA</td>
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<tr>
<td>Fat</td>
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<td>0.24</td>
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</table>

\(^a\)BRD Incidence = untreated (0) vs. treated (0), NoTrt is equal to; 0 = non treated cattle, 1 = cattle treated once, 2 = cattle treated twice, 3+ = cattle treated three or more times, HCW = hot carcass weight, REA = rib-eye area, Fat = subcutaneous fat cover, and MarbS = marbling score.  
\(^b\)TRT = BRD incidence or NoTrt; CG = contemporary group; HD(CG) = final harvest date within contemporary group; Sex = steer or heifer, AgeH = day of age at harvest.
Table 4. Least square means for performance and carcass measures of cattle diagnosed with BRD and those considered healthy.

<table>
<thead>
<tr>
<th>Item*</th>
<th>Least Square Means</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Untreated</td>
</tr>
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</tr>
<tr>
<td>Warm-up ADG,** kg/d</td>
<td>1.55</td>
</tr>
<tr>
<td>Overall ADG,** kg/d</td>
<td>1.44</td>
</tr>
<tr>
<td>Final Weight,** kg</td>
<td>532</td>
</tr>
<tr>
<td>HCW,** kg</td>
<td>320</td>
</tr>
<tr>
<td>Fat,** mm</td>
<td>12.19</td>
</tr>
<tr>
<td>MarbS,* b</td>
<td>5.60</td>
</tr>
</tbody>
</table>

*BRD Incidence = untreated (0) vs. treated (1). Warm-up ADG = early feeding period, On-test ADG = late feeding period, Overall ADG = total feedlot period, Final Weight = last weight before harvest, HCW = hot carcass weight, REA = rib-eye area, Fat = subcutaneous fat cover, and MarbS = marbling score.

b2.00 = Practically devoid; 3.00 = Traces; 4.00 = slight; 5.00 = small; 6.00 = Modest; 7.00 = Moderate; 8.00 = Slightly abundant; 9.00 = Moderately abundant; 10.00 = Abundant.

cDiff = untreated minus treated.

* P-value = < 0.05 & ** P-value = < 0.01.
Table 5. Percentage of carcass quality grade by the number of bovine respiratory disease (BRD) treatment category.

<table>
<thead>
<tr>
<th>Item&lt;sup&gt;a&lt;/sup&gt;</th>
<th>Number of BRD treatment category&lt;sup&gt;b&lt;/sup&gt;</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>0</td>
</tr>
<tr>
<td>Prime</td>
<td>1.53</td>
</tr>
<tr>
<td>Choice</td>
<td>79.46</td>
</tr>
<tr>
<td>Select</td>
<td>18.35</td>
</tr>
<tr>
<td>Standard</td>
<td>0.66</td>
</tr>
</tbody>
</table>

<sup>a</sup>USDA carcass quality grade category.

<sup>b</sup>0 = non treated cattle, 1 = cattle treated once, 2 = cattle treated twice, 3+ = cattle treated three or more times.
Table 6. Variance component and heritability estimates for health, performance and carcass traits obtained from single trait sire model analysis.

<table>
<thead>
<tr>
<th>Itema</th>
<th>VA</th>
<th>VP</th>
<th>h²</th>
</tr>
</thead>
<tbody>
<tr>
<td>BRD incidence</td>
<td>0.48</td>
<td>6.92</td>
<td>0.07 ± 0.04</td>
</tr>
<tr>
<td>NoTrt</td>
<td>0.01</td>
<td>0.22</td>
<td>0.05 ± 0.04</td>
</tr>
<tr>
<td>Warm-up ADG</td>
<td>0.62</td>
<td>1.09</td>
<td>0.57 ± 0.09</td>
</tr>
<tr>
<td>On-test ADG</td>
<td>0.12</td>
<td>0.22</td>
<td>0.55 ± 0.09</td>
</tr>
<tr>
<td>Overall ADG</td>
<td>0.11</td>
<td>0.16</td>
<td>0.67 ± 0.09</td>
</tr>
<tr>
<td>Final Weight</td>
<td>3263.65</td>
<td>4612.18</td>
<td>0.71 ± 0.10</td>
</tr>
<tr>
<td>HCW</td>
<td>2352.47</td>
<td>3242.19</td>
<td>0.73 ± 0.10</td>
</tr>
<tr>
<td>REA</td>
<td>0.50</td>
<td>0.89</td>
<td>0.56 ± 0.08</td>
</tr>
<tr>
<td>Fat</td>
<td>0.005</td>
<td>0.01</td>
<td>0.34 ± 0.07</td>
</tr>
<tr>
<td>Marb</td>
<td>0.35</td>
<td>0.58</td>
<td>0.61 ± 0.09</td>
</tr>
</tbody>
</table>

aBRD Incidence = untreated (0) vs. treated (1), NoTrt is equal to; 0 = non treated cattle, 1 = cattle treated once, 2 = cattle treated twice, 3 = cattle treated three or more times, Warm-up ADG = early period of feedlot, On-test ADG = late period of feedlot, Overall ADG = total feedlot period, HCW = hot carcass weight, REA = rib-eye area, Fat = fat cover, and Marb = marbling score.

bVA = additive genetic variance, VP = phenotypic variance (total variance), h² = heritability.
Table 7. Phenotypic and genetic correlations among two measures of bovine respiratory disease incidence and performance and carcass traits estimated for a bivariate sire model.

<table>
<thead>
<tr>
<th>Item (^a)</th>
<th>BRD incidence</th>
<th>NoTrt</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>(r_P)</td>
<td>(r_A)</td>
<td>(r_P)</td>
</tr>
<tr>
<td>Warm-up ADG</td>
<td>-0.05</td>
<td>-0.90 ± 0.20</td>
<td>-0.05</td>
</tr>
<tr>
<td>On-test ADG</td>
<td>0.01</td>
<td>0.14 ± 0.25</td>
<td>0.01</td>
</tr>
<tr>
<td>Overall ADG</td>
<td>-0.02</td>
<td>-0.35 ± 0.22</td>
<td>-0.02</td>
</tr>
<tr>
<td>Final Weight</td>
<td>-0.03</td>
<td>-0.43 ± 0.21</td>
<td>-0.03</td>
</tr>
<tr>
<td>HCW</td>
<td>0.00</td>
<td>0.00 ± 0.23</td>
<td>-0.01</td>
</tr>
<tr>
<td>REA</td>
<td>0.00</td>
<td>0.02 ± 0.23</td>
<td>0.00</td>
</tr>
<tr>
<td>Fat</td>
<td>-0.00</td>
<td>-0.03 ± 0.26</td>
<td>0.00</td>
</tr>
<tr>
<td>Marb</td>
<td>-0.02</td>
<td>-0.42 ± 0.21</td>
<td>-0.01</td>
</tr>
</tbody>
</table>

\(^a\)BRD Incidence = untreated (0) vs. treated (1), NoTrt is equal to; 0 = non treated cattle, 1 = cattle treated once, 2 = cattle treated twice, 3 = cattle treated three or more times, Warm-up ADG = early period of feedlot, On-test ADG = late period of feedlot, Overall ADG = total feedlot period, HCW = hot carcass weight, REA = rib-eye area, Fat = fat cover, and Marb = marbling score.

\(^b\) Genetic correlation and \(r_P\) = phenotypic correlation.

\(^c\) Phenotypic correlations were calculated as a ratio of phenotypic covariance estimates to the product of respective phenotypic standard deviation estimates.
CHAPTER 5.
AN EVALUATION OF BOVINE RESPIRATORY INCIDENCE IN PREWEAN CALVES: FIXED SOURCES OF VARIATION AND GENETIC PARAMETERS

A paper to be submitted to The Journal of Animal Science

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2Correspondence: 2255 Kildee Hall, Iowa State University, Ames, IA 50011 (phone: 515-294-9269; fax: 515-294-2401; E-mail: jreecy@iastate.edu).
ABSTRACT: The primary objective of this study was to estimate variance components and the associated heritability of BRD incidence in young beef calves prior to weaning. The second objective was to investigate the impact of BRD incidence and treatment frequency on weaning weight. This study used records from 1,499 head of young pre-wean calves from the Iowa State University Teaching farm. Calves were born from the spring of 1997 to the fall of 2006, with 110 sires represented in the entire population. A BRD incidence rate of 11.14% was observed, of which 83.2% were treated once, 14.4% were treated twice, and 2.4% were treated three times or more. The incidence of BRD ($P < 0.37$) and the number of treatment ($P < 0.76$) had no significant effect on weaning weight. Calves born with heavier birth weights tended to have a decreased BRD incidence rate ($P < 0.10$). The LS mean estimate for birth weight for cattle never treated was $40.05 \pm 0.18$ kg, compared to cattle treated at least three times of $44.88 \pm 2.67$ kg. Heritability estimates for the entire population for BRD resistance and number of treatments were $0.12 \pm 0.06$ and $0.08 \pm 0.05$, respectively. Estimates of heritability for weaning weight were $0.22 \pm 0.11$ and the estimate for birth weight was $0.63 \pm 0.14$. The genetic correlation estimates for BRD incidence with weaning weight and birth weight were low ($0.00 \pm 0.37$ and $0.03 \pm 0.27$, respectively). The same estimate for the number of BRD treatment with weaning weight and birth weight was $0.04 \pm 0.42$ and $0.19 \pm 0.30$, respectively. When cattle were separated and analyzed in different groups based on breed the heritability estimate for BRD resistance was $0.17 \pm 0.14$ and $0.00 \pm 0.05$ for Angus and Simmental calves, respectively. Results here indicate that selection for BRD resistance during the pre-weaning period is possible, with favorable association with birth weight and little effect on weaning weight.

Key words: bovine respiratory disease, cattle, disease resistance, genetics
INTRODUCTION

Bovine respiratory disease (BRD) is the most costly health issue facing the cattle industry (Snowder, 2005). Estimates of the cost to treat one incidence of respiratory disease have been estimated to range from $12.39 to $15.57 (Edwards, 1996; Faber et al., 1999; USDA APHIS, 2001). This estimate only includes cost of pharmaceuticals and treatment supplies, but does not include the loss of production such as labor fees and indirect loss due to lower performance. The best defense that cattle producers have against BRD is prevention. Taking steps to ensure prevention is extremely important because of the possibility of an epidemic outbreak and compounding economic ramifications that BRD presents. Prevention of BRD is best accomplished through vaccination and management, specifically, paying close attention during high stress periods particularly during times of stress such as weaning and shipping.

Factors that contribute to respiratory diseases in cattle can be broken down into three different segments: viruses, bacteria, and stress. Cattle of all ages can be affected by respiratory disease; however, they are the most susceptible during the decay of passive immunity in young calves, weaning time, and entrance into the feedlot as cattle are introduced to a wide range of stress and pathogens (Muggli-Cockett et al., 1992). Stress factors that are commonly associated with BRD include (but certainly are not limited to): extreme heat and cold, dampness, humidity, anxiety, nutritional deficiencies, transportation, overcrowding, and commingling cattle from different sources. Common viral agents that are implicated in BRD include infectious bovine rhinotracheitis (IBR), bovine viral diarrhea virus (BVDV), bovine respiratory syncytial virus (BRSV), and parainfluenza type 3 (PI-3). In addition, bacterial strains associated with BRD include Mannheimia haemolytica,
Pasteurella multocida, Haemophilus somnus, and mycoplasma (Ellis et al., 2001; Plummer et al., 2004).

Heritability estimates for resistance to BRD have previously been reported in pre-wean calves by Muggli-Cockett et al. (1992) ($h^2 = 0.10$), and Snowder et al. (2005) ($h^2 = 0.00$ to $0.26$). Selection for reduced BRD incidence would be beneficial to the entire cattle industry. The primary objective of this study was to estimate variance components and the associated heritability of BRD resistance in young beef calves prior to weaning. The second objective was to investigate the impact of BRD incidence and treatment frequency on weaning weight.

**MATERIALS AND METHODS**

The data analyzed within this study were obtained from 1,499 head of cattle with known purebred sires. Performance, sire registration numbers and health records were obtained from the Iowa State University Teaching Farm located in Ames, Iowa. The majority of this cow herd is comprised of purebred Angus and Simmental cattle, calving both in the spring and fall periods. Spring and fall calving cows are maintained in separate herds and calves in both seasons are provided a creep ration (with a corn and oat based). Spring cows are grazed on pasture throughout the lactation phase, whereas fall cows are exposed to pasture part of the lactation phase and are then moved onto dry-lots during part of this time period.

**Health Management**

The health protocols were consistent across years, with calves receiving vaccination for clostridial, haemophilus somnus, infectious bovine rhinotracheitis (IBR), bovine viral diarrhea virus (BVDV), bovine respiratory syncytial virus (BRSV), and parainfluenza type 3
(PI-3) by 200 days of age. Common symptoms associated with BRD include: breathing difficulty such as noisy or rapid breathing, coughing, decreased appetite, lethargy, droopy ears, eye discharge, fever, nasal discharge, open mouthed breathing, and death. Diagnosis of disease classification was maintained by the farm manager across years.

**Statistical Analysis**

The GLM procedure of SAS (Version 9.1; SAS Inst. Inc., Cary, NC) was used to estimate the effects of BRD on weaning weight and to examine the effect of birth weight on BRD incidence. The data set evaluated for weaning weight was reduced to 955 head due to missing data (Table 2). BRD incidence is defined as a binary classification of 0 for untreated and 1 for treated cattle (based on at least one treatment for respiratory reasons). The number of BRD treatment (NoTrt) was defined as the following: 0 if cattle were never treated for BRD, 1 if cattle were treated once for BRD, 2 if cattle were treated twice for BRD, and 3+ if cattle were treated three times or greater (thought to be suffering from chronic illness with BRD).

The following model was used to estimate the effect of BRD on weaning weight:

\[
y_{ijklm} = TRT_i + CG_j + Sex_k + BW_l + AgeW_l + BoDamm_m + \epsilon_{ijklm}
\]

where \(y_{ijklm}\) = the trait measured on calf \(l\), in treatment \(i\), in contemporary group \(j\), of sex \(k\), and of breed of dam \(m\); TRT\(_i\) = fixed effect of BRD Incidence \(i\) or NoTrt \(i\); CG\(_j\) = fixed effect of contemporary group \(j\) (based on calving season and year of cattle); Sex\(_k\) = fixed effect of sex \(k\) (bull, steer or heifer); BW\(_l\) = linear effect of birth weight of calf \(l\); AgeW\(_l\) = linear effect of age at weaning of calf \(l\); BoDamm\(_m\) = fixed effect of breed of dam \(m\); \(\epsilon_{ijklm}\) = residual with \(\epsilon_{ijklm} \sim N(0, \sigma^2)\). The effects of BRD on birth weight was assessed with the following model:
\[ y_{ijklm} = TRT_i + CG_j + Sex_k + BoDam_l + \epsilon_{ijklm} \]

where \( y_{ijklm} \) = the trait measured on calf \( m \), in treatment \( i \), in contemporary group \( j \), of sex \( k \), and in breed of dam \( l \); \( TRT_i \) = fixed effect of BRD Incidence \( i \) or NoTrt \( i \); \( CG_j \) = fixed effect of contemporary group \( j \) (based on calving season and year of cattle); \( Sex_k \) = fixed effect of sex \( k \) (bull, steer or heifer); \( BoDam_l \) = fixed effect of breed of dam \( l \); \( \epsilon_{ijklm} \) = residual with \( \epsilon_{ijklm} \sim N(0, \sigma^2) \).

Genetic parameters were estimated using a sire model within MTDFREML (Boldman et al. 1995). Three different analyses were conducted: estimates based on records from the entire population, estimate based only on purebred Angus records, and estimates based on purebred Simmental records. In all cases, a three generation sire pedigree was constructed from data provided by the American Angus Association and the American Simmental Association. The analysis of the entire population used a total of 304 animals within the pedigree file and encompassed 110 different sires with direct pre-wean progeny. The pedigree included 22 inbred animals with an average inbreeding coefficient of 3.20%. The model used within MTDFREML for each trait was as follows: \( y = Xb + Za + e \), where \( y \) = vector of observations; \( b \) = vector of fixed effects, \( a \) = vector of random additive sire effects, which utilizes the numerator relationship matrix among sires; \( e \) = vector of residuals. The incidence matrices relating observations to fixed effects and random animal are \( X \) and \( Z \), respectively. Fixed effects included in the analysis of BRD incidence and number of treatments was contemporary group (based on calving season within year) and breed of dam, along with a linear covariate of individual birth weight. Similar fixed effects were included in the analysis of birth weight except for the linear covariate of birth weight and the effect of sex was added. The analysis of weaning weight included similar fixed effects as the analysis.
of BRD incidence and number of treatments with an additional linear covariate of age at weaning.

Convergence was defined when the variance of simplex of -2 logL was less than $1 \times 10^{-9}$. After initial convergence was attained, three restarts were performed to ensure global convergence. For single trait models, variance component estimates were used to calculate heritability as the ratio of: $(4 \times V_A) / V_P$ (Falconer and Mackay, 1996). Bivariate models were utilized to estimate genetic correlations for BRD with weaning and birth weight. Phenotypic correlations were calculated as the ratio of phenotypic covariance estimates to the product of respective phenotypic standard deviation estimates.

RESULTS AND DISCUSSION

Bovine respiratory disease was observed at a rate of 11.14% ($n = 167$) across all years. The highest incidence (60%) of disease occurred during the fall of 2005, and the lowest incidence (0.00%) was detected in the fall of 1998, 1999, and spring 1998 (Figure 1). Mean birth and weaning weights were $40 \pm 21$ kg and $252 \pm 44$ kg, respectively. The average age at weaning was $177 \pm 25$, and the average age of first treatment was $120 \pm 39$. Among cattle treated for BRD, 83.2% were treated once, 14.4% were treated twice, and 2.4% were treated three times or more. There was a death rate of pre-wean calves of 1.44% (22 head). The population consisted of 28% bulls, 25% steers, and 47% heifers.

Sources of variation for BRD incidence and the number of BRD treatments on weaning weight are presented in Table 1. Neither BRD incidence nor NoTrt had a significant effect on weaning weight ($P < 0.37$) and ($P < 0.76$). This result indicates that BRD infection may not have been severe enough to lower performance or that treatment for BRD stricken cattle was effective in combating disease. Calves with heavier birth weights tended to have
an increased incidence of BRD ($P < 0.10$) and NoTrt ($P < 0.02$). The least square means for birth weight of cattle never treated was $40.05 \pm 0.18$ kg, whereas cattle treated at least once was $40.91 \pm 0.47$ kg. There tended ($P < 0.07$) to be a significant difference in birth weight between cattle never treated ($40.05 \pm 0.18$ kg) and cattle treated three times or more ($44.88 \pm 2.67$ kg).

**Genetic Parameters**

Estimates from single trait analysis of measures for respiratory disease, weaning weight, and birth weight are presented in Table 3. Heritability estimates for BRD incidence and number of treatments was $0.12 \pm 0.06$ and $0.08 \pm 0.05$, respectively. These estimates are similar to those reported by Muggli-Cockett et al. (1992; $h^2 = 0.10$), and Snowder et al. (2005; $h^2 = 0.00$ to $0.26$) in pre-wean calves. Estimates of heritability for birth and weaning weights were $0.63 \pm 0.14$ and $0.22 \pm 0.11$, respectively. Selection for lower BRD incidence during the pre-weaning period is possible based on the heritability estimates obtained from this population.

The estimate of heritability for BRD incidence in purebred Angus calves was $0.17 \pm 0.14$ and was $0.00 \pm 0.05$ in purebred Simmental calves. There were 69 Angus sires and 41 Simmental sires used within this analysis. These results indicate that selecting for BRD resistance may be more feasible in Angus cattle within this population when compared to the Simmental breed. Possible differences in the heritability estimates between breeds are likely due to breed differences observed in terms of additive and phenotypic variances (Table 3). Within this population the additive variance for Angus cattle is considerably larger with relatively similar estimates for phenotypic variance seen between both breeds.
Phenotypic and genetic correlations among BRD incidence, number of BRD treatments, weaning weight, and birth weight were estimated from records on the entire population (Table 4). The phenotypic correlations between all traits were low, ranging between 0.00 and 0.01. The genetic correlation estimates for BRD incidence with weaning weight and birth weight were low (0.00 ± 0.37 and 0.03 ± 0.27, respectively). However, slightly higher genetic correlation estimates were obtained for the number of BRD treatment with weaning weight and birth weight (0.04 ± 0.42 and 0.19 ± 0.30, respectively). Also, the favorable genetic correlation between birth weight and BRD incidence and frequency indicates that genetic selection for either measure will have a desirable effect on the other.

Additional work was completed for the entire population in regards to heritability estimates and genetic correlations using two different bivariate analyses. Similar methods were used as was reported in Schneider et al. (Chapter 4). Including BRD incidence within the model was examined in order to determine the effect this might have on the estimated variance components. Similar results were seen from both of these two procedures with no change on heritability estimates from what is reported in this study (Data not shown).

Conclusion

This study utilized field data from pre-wean cattle from the Iowa State University Teaching Farm. Though the heritability estimate for BRD was low, results here illustrate that breeding programs could be developed to incorporate BRD resistance into selection programs to improve cattle health. In addition, this study indicates that selection for BRD resistance may have little effect on weaning weight due to the low correlation estimate and large SE. Selection for reduced BRD incidence could be beneficial to cattle producers in terms of cattle health.
LITERATURE CITED


Figure 1. The distribution of bovine respiratory disease (BRD) incidence by calving season.

\*Percentage of cattle = the percentage of cattle treated for respiratory reasons.

\*Overall = percentage of calves treated across all years.
Table 1. Significance tests for fixed sources of variation for weaning weight in pre-wean calves by type of BRD measurement used.

<table>
<thead>
<tr>
<th>Item&lt;sup&gt;a&lt;/sup&gt;</th>
<th>n</th>
<th>R²</th>
<th>TRT</th>
<th>CG</th>
<th>Sex</th>
<th>BWT</th>
<th>AgeW</th>
<th>BoDam</th>
</tr>
</thead>
<tbody>
<tr>
<td>BRD incidence</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Weaning Wt.</td>
<td>955</td>
<td>0.71</td>
<td>0.37</td>
<td>&lt; 0.01</td>
<td>&lt; 0.01</td>
<td>&lt; 0.01</td>
<td>&lt; 0.01</td>
<td>&lt; 0.01</td>
</tr>
<tr>
<td>NoTrt</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Weaning Wt.</td>
<td>955</td>
<td>0.71</td>
<td>0.76</td>
<td>&lt; 0.01</td>
<td>&lt; 0.01</td>
<td>&lt; 0.01</td>
<td>&lt; 0.01</td>
<td>&lt; 0.01</td>
</tr>
</tbody>
</table>

<sup>a</sup>BRD Incidence = untreated (0) vs. treated (1), NoTrt is equal to; 0 = non treated cattle, 1 = cattle treated once, 2 = cattle treated twice, 3+ = cattle treated three or more times; Weaning Wt. = weight of cattle at weaning time.

<sup>b</sup>TRT = BRD incidence or NoTrt; CG = contemporary group; Sex = bull, steer, or heifer; BWT = weight at birth; AgeW = age of calf at weaning time; BoDam = breed of dam.
Table 2. Significance tests for fixed sources of variation for birth weight in pre-wean calves by type of BRD measurement used.

<table>
<thead>
<tr>
<th>Item</th>
<th>n</th>
<th>R²</th>
<th>TRT</th>
<th>CG</th>
<th>Sex</th>
<th>BoDam</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>BRD incidence</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Birth Wt.</td>
<td>1,499</td>
<td>0.18</td>
<td>0.09</td>
<td>&lt; 0.01</td>
<td>&lt; 0.01</td>
<td>&lt; 0.01</td>
</tr>
<tr>
<td><strong>NoTrt</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Birth Wt.</td>
<td>1,499</td>
<td>0.19</td>
<td>0.15</td>
<td>&lt; 0.01</td>
<td>&lt; 0.01</td>
<td>&lt; 0.01</td>
</tr>
</tbody>
</table>

aBRD Incidence = untreated (0) vs. treated (1), NoTrt is equal to; 0 = non treated cattle, 1 = cattle treated once, 2 = cattle treated twice, 3+ = cattle treated three or more times; Birth Wt. = weight at birth.
bTRT = BRD incidence or NoTrt; CG = contemporary group; Sex = bull, steer, or heifer; BoDam = breed of dam.
Table 3. Variance component and heritability estimates for health and performance traits obtained from single trait sire model analysis.

<table>
<thead>
<tr>
<th>Itema</th>
<th>n</th>
<th>VA</th>
<th>VP</th>
<th>h²</th>
</tr>
</thead>
<tbody>
<tr>
<td>Entire Population</td>
<td>1,499</td>
<td>0.91</td>
<td>7.70</td>
<td>0.12 ± 0.06</td>
</tr>
<tr>
<td>BRD incidence</td>
<td>0.91</td>
<td>7.70</td>
<td>0.12 ± 0.06</td>
<td></td>
</tr>
<tr>
<td>NoTrt</td>
<td>0.01</td>
<td>0.13</td>
<td>0.08 ± 0.05</td>
<td></td>
</tr>
<tr>
<td>Birth Weight</td>
<td>88.85</td>
<td>140.85</td>
<td>0.63 ± 0.14</td>
<td></td>
</tr>
<tr>
<td>Weaning Weight</td>
<td>668.11</td>
<td>3024.49</td>
<td>0.22 ± 0.11</td>
<td></td>
</tr>
<tr>
<td>Angus only</td>
<td>477</td>
<td>1.34</td>
<td>8.00</td>
<td>0.17 ± 0.14</td>
</tr>
<tr>
<td>BRD incidence</td>
<td>1.34</td>
<td>8.00</td>
<td>0.17 ± 0.14</td>
<td></td>
</tr>
<tr>
<td>Simmental only</td>
<td>646</td>
<td>0.00</td>
<td>7.76</td>
<td>0.00 ± 0.05</td>
</tr>
<tr>
<td>BRD incidence</td>
<td>0.00</td>
<td>7.76</td>
<td>0.00 ± 0.05</td>
<td></td>
</tr>
</tbody>
</table>

aEntire Population = all animals; BRD Incidence = untreated (0) vs. treated (1), NoTrt is equal to; 0 = non treated cattle, 1 = cattle treated once, 2 = cattle treated twice, 3+ = cattle treated three or more times; Birth Weight = weight at birth; Weaning Weight = weight of cattle at weaning time; Angus only = angus calves; Simmental only = simmental calves.

bVA = additive genetic variance, VP = phenotypic variance (total variance), h² = heritability.
### Table 4. Phenotypic and genetic correlations among two measures of BRD incidence and performance traits estimated from a bivariate sire model.

<table>
<thead>
<tr>
<th>Item</th>
<th>BRD incidence</th>
<th>NoTrt</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>r_P</td>
<td>r_A</td>
</tr>
<tr>
<td>Weaning Weight</td>
<td>0.00</td>
<td>0.00 ± 0.37</td>
</tr>
<tr>
<td>Birth Weight</td>
<td>0.00</td>
<td>0.03 ± 0.27</td>
</tr>
</tbody>
</table>

*a*Weaning Weight = weight of cattle at weaning time; Birth Weight = weight at birth

*b*BRD Incidence = untreated (0) vs. treated (1), NoTrt is equal to; 0 = non treated cattle, 1 = cattle treated once, 2 = cattle treated twice, 3+ = cattle treated three or more times

*c*\(r_A\) = genetic correlation and \(r_P\) = phenotypic correlation.

*d*Phenotypic correlations were calculated as a ratio of phenotypic covariance estimates to the product of respective phenotypic standard deviation estimates.
CHAPTER 6.
GENERAL CONCLUSIONS

Cattle producers constantly struggle to develop new breeding schemes in efforts to enhance the potential genetic output of their operations. One new and exciting topic recently has involved the possibility of breeding for disease resistance. Due to the sizeable economic impact that bovine respiratory disease (BRD) has on the entire cattle industry from cow/calf producers to feedlot operations, this disease has been a recent focus point.

The underlying objective of this research was to quantify the role of genetics on susceptibility and resistance to bovine respiratory disease. The data used within this study consisted of performance, carcass, health, and genetic records from cattle in two different environments. The first is during the pre-weaning setting with calves still nursing cows on pasture and cattle fed through typical commercial feedlot environments. All cattle included in the genetic analysis of the feedlot records consisted of Angus sires, whereas pre-wean data consisted of Angus and Simmental sires. Heritability estimates involving both treated and untreated cattle as well as the different number of treatment relating to respiratory infection were determined. Along with this, phenotypic and genetic correlations were estimated for BRD incidence and number of treatments with birth weight, weaning weight, warm-up ADG (early feeding period; initial 4 to 6 weeks), on-test ADG (late feeding period; end of warm-up period until harvest), overall ADG (total feedlot period), final weight, hot carcass weight, rib-eye area, subcutaneous fat cover, and marbling score. Also, effects that BRD incidence and lung lesion scores taken at harvest have on performance and carcass traits were evaluated.

Results from this study illustrate that BRD incidence had adverse effects on average daily gain during the early phase of the feedlot period, as well as a long lasting effects on
overall ADG through the feedlot phase. Also, BRD incidence decreased hot carcass weight, rib-eye area, subcutaneous fat cover, and marbling score. When the number of treatments was evaluated, the results on most performance and carcass traits were similar; however, the negative effects increased as the number of treatment is increased.

Furthermore, the analysis of the presence of lung lesions at harvest revealed no significant effects on traits analyzed within this study. However, when the severity of lung lesion was considered, there was no significant difference between the different scoring categories utilized in the study, except for decreased production when active bronchial lymph nodes were observed. In pre-wean cattle there was no effect of BRD on weaning weight, however calves heavier at birth tended to suffer more from respiratory complications.

Overall, there is a clear economic consequence associated with bovine respiratory disease. As a result, cattle producers are interested in the ability of breeding cattle that are genetically resistant to BRD. Findings from this study illustrate that selection for resistance for BRD may be possible, though heritability estimates are low in magnitude. Estimates of genetic correlations for most performance and carcass traits were favorable with BRD incidence, thus indicating that genetic selection for reduction of BRD would not adversely affect other production traits important to profitability.
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