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THE EFFECT OF CALFHOOD PNEUMONIA ON HEIFER AND COW SURVIVAL AND PERFORMANCE

A Thesis in

Animal Science

by

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ABSTRACT

Bovine Respiratory Disease Complex (BRD) is a prevalent and economically important disease in growing cattle. The complexity of the disease is due to its multifactorial nature; it involves intricate interactions between bacterial agents, viral agents, the environment, and other stressors. The term BRD is most commonly used to describe a host of complex respiratory issues that are present in cattle, including upper respiratory infections and various forms of pneumonia. BRD cases for this study were defined as calves that were treated for “pneumonia” in the first six months of life, so the words pneumonia and BRD are used interchangeably henceforth. In addition to the obvious costs of treatment, BRD affects calf survivability, age at first calving, and cow performance (body weight and milk yield).

Health events, cull records, and calving dates were obtained from Holstein calves (n=1629) born between January 2000 and April 2015 on the Penn State University (PSU) dairy herd to analyze survivability. The GLIMMIX and LIFETEST procedures of SAS were used to determine what factors significantly affected pneumonia incidence, survival, and age at first calving (AFC). Year of birth (P<0.0001) and season of birth (P=0.0003) were significant predictors for pneumonia incidence. Calves born in months September through November were most likely to have a pneumonia treatment recorded (19.02%). Cattle treated for calf-hood pneumonia did not survive (mean sold age: 1507.91±54.33 days) as long as the calves that were not treated for pneumonia (mean sold age:...
1612.49±22.70 days). Pneumonia incidence (P=0.0189) had significant effects on survival to 24-months of age. Cattle not treated for pneumonia had 1.649 greater odds of surviving to 24 months than those who were treated for pneumonia. Cattle treated for pneumonia had a slightly older mean for AFC (770.94±7.30 days) than healthy cattle (761.97±2.79 days), but this was not significant.

After analyzing the effects the disease has on herd survivability, it was important to determine if animals once treated for BRD performed as well as their healthy herdmates. The health events of the cattle were obtained along with 708,162 daily milk yield observations and 560,059 daily body weight observations. The performance data was analyzed using a mixed model in ASREML where daily milk yield or daily body weight was determined by the fixed effects (lactation, week of lactation within lactation group, pneumonia status, pneumonia status within lactation group, pneumonia status within week of lactation and lactation group, and age group) and random effects (year-week within lactation group, cow, cow within lactation, and residual error). For milk yield, the effect of pneumonia (P=0.941) was not significant across lactations and stage of lactation. The significant differences in milk yield between diseased and healthy cattle tended to occur in late lactation. Pneumonia (P=0.332) and pneumonia within lactation group (P=0.360) were not significant indicators for body weight. Therefore, pneumonia significantly affected herd survivability and age at first calving; however, this study failed to demonstrate significance differences in milk yield and body weight for those calves that did survive.
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Chapter 1

Review of the Literature

Overview

Bovine Respiratory Disease Complex (BRD) is the most important disease in growing cattle based on prevalence and economic cost (Callan and Garry, 2002; Griffin et al., 2010). The National Animal Health Monitoring System used producer interviews to estimate that 2.4% of cows in 2002 and 2.9% of cows in 2007 were diagnosed with BRD. The NAHMS also stated that 18.1% of preweaned heifers and 11.2% of weaned heifers were infected with the respiratory disease in 2010 (USDA, 2002; USDA, 2009; and USDA, 2012). BRD affects both the beef and dairy industry and is commonly called shipping fever, enzootic pneumonia, and bronchopneumonia (Callan and Garry, 2002). Despite the occasional variety of nomenclature, the term Bovine Respiratory Disease is most commonly used to describe a host of respiratory issues that are present in cattle and influenced by many stressors (Cusack, 2003). The complexity of the disease is due to its multifactorial nature. It involves intricate interactions between bacterial agents, viral agents, the environment, and other stressors, making it hard to manage and prevent infection. Many of the causative agents of this complex are ubiquitous and can be isolated from the respiratory tree of healthy cattle. The presence of stressors interrupt the copacetic state and allows the opportunistic pathogens to infect the cattle’s lower
respiratory (Taylor, 2010; Filion, 1984). Although many years of research have been dedicated to BRD, the mortality and morbidity associated with the disease have not significantly decreased in dairy cattle. This may be because of the continual use of predisposing management techniques or because much of the research is centered around the beef industry (Callan and Garry, 2002).

**Predisposing Risk Factors**

Certain risk factors aid disease transmission by increasing pathogen abundance and suppressing immune response (Callan and Garry, 2002). These factors include transportation, weaning, diet, comingling, and season or climate.

**Transportation Stress**

Due to the high incidence of infection following transport of cattle, BRD is commonly labeled shipping fever. In North America, most beef cattle are transported at least once. Plasma cortisol levels, a stress indicator, can be greatly increased during travel (Crooshank et al., 1979; Filion et al., 1984). Travel and transportation has thus become an important area of research in an attempt to identify the component of transportation that most affects BRD incidence. Although there are many subcomponents of transportation (sorting, loading, distance, etc.), distance and time traveled are the most researched components.

**Long distance vs. short distance**

Cole et al. (1988) experimentally altered cattle’s travel time. Cattle were put into three categories based on time traveled: 12 hour, 24 hour, and a control group. The cattle that only traveled for 12 hours had higher morbidity and mortality rates than the cattle
from the other two groups. The short haul group (12 hour transport) had a 54% morbidity rate in comparison to a 22% rate of the control group and 24% of the long haul (24 hour group). A large percentage (50%) of the short haul group’s morbidity occurred after day 5 of unloading whereas the other two groups saw few cases after day 5.

Following the same general trend, the short haul group had a 24% mortality rate in comparison to the 4% and 8% for the control group and long haul group, respectively.

The cattle that traveled only for 12 hours arrived at the feedlot at 8pm while the 24-hour cattle arrived at 8am. Health of the cattle was recorded before transport by taking rectal temperature and serum levels; the short and long haul groups had mean rectal temperatures of 39 degrees Celsius and the control group had a mean rectal temperature of 39.1 degrees Celsius. The control group was forced to fast during the 24 hours so that the stress of fasting was included. The 24-hour group had to fast during transport; however, the 12-hour group had to fast 12 hours during transport and then fast 12 hours in the pen, so the authors believed this could have been a double stressor on the group.

Other studies suggest longer distance traveled increase risk of BRD incidence (Sanderson et al., 2008; Cernicchiaro et al., 2012). The inconsistent conclusions have convinced some researchers that the loading and unloading stages of transport are more directly related to BRD incidence than the distance traveled (Stern, 1982; Taylor et al., 2010; Grandin, 1997). This was consistent with previous studies suggesting that handling stress suppresses immune function (Kelley et al., 1981; Blecha et al., 1984). Grandin (1997) suggested designing trucks and ramps to reduce cattle stress and injuries during the
loading and unloading process. Her recommendations included using narrow ramps; 76 cm for adult cows and less than 76 cm for calves.

**Weather and Climate**

The highest incidence of BRD occurs in the autumn and early winter (MacVean et al., 1986; Cusack, 2003; Taylor et al., 2010). However, there has been no causal link between BRD and climate. Autumn is the busiest beef-marketing season; more cattle are present at one time, thus potentially increasing the chance of having at-risk cattle infect others (Taylor et al., 2010). This confounds the effect that the season may have on incidence rates.

Researchers make two arguments in regards to climate effect: some suspect that the extreme temperatures are the reason for increased incidence during fall and winter, while others suggest a sudden change or variability in temperature increases the disease incidence. Callan and Garry (2002) credit both rapidly changing environments and extreme temperatures as risk factors for disease transmission.

A four-year study showed a 2 to 8 fold increased risk of fatal pneumonia in calves entering the feedlot in November versus cattle that enter in September (Ribble et al., 1995). Of the 4 years, the highest disease incidence happened in 1985 (year with the coldest temperatures and most snowfall) and 1987 (year with the warmest temperatures and lowest snowfall). This followed the concept that extreme temperatures affected disease transmission.

MacVean et al. (1986) conducted an environmental epidemiologic study at a feedlot northeast of Greeley, Colorado. The study concluded that the range of daily
temperature is closely linked to BRD. However, Alexander et al. (1989) found that increased variation correlated with decreased incidence in BRD. There was a decrease of 0.5 cases of disease per 10,000 head-days expected for each degree of average temperature change. The two studies may have different results because the latter study measured temperature variation on a day-to-day basis, but did not consider the within-day changes that the MacVean et al. (1986) study took into consideration.

These studies demonstrate that the data on climate are inconclusive, but do give indications that extreme temperatures and rapid temperature change have an influence on disease incidence.

**Weaning, commingling, and preconditioning calves**

Weaning has been a preconditioning technique that many believe can increase the chances of acquiring BRD, if done improperly. Commingling has been thought to increase the risk (Lorenz et al., 2011; Step et al., 2008). Step et al. (2008) conducted an experimental study at Willard Sparks Beef Research Center (WSBRC) in Stillwater, OK where calves from the market, calves from a singular ranch, and commingled calves (some from market and some from ranch) were evaluated for BRD risk by measuring incidence, antibodies, and treatment. Market cattle were denoted “market” and considered high risk and exposed. The ranch cattle were divided into three groups: “weaned”, high risk and unexposed cattle who were weaned and immediately sent to WSBRC; “weaned45”, unknown risk cattle who were weaned and remained on ranch 45 day before shipping but received no vaccinations; and “weanvac45”, low risk cattle who were allowed to stay at ranch for 45 days after weaning and vaccinated with a modified
live viral vaccine. Upon arrival at WSBRC, market cattle, weaned, and weaned were vaccinated. This study showed the effectiveness of preconditioning programs in reducing incidence. Market steers had greater morbidity rates than ranch originated steers. Commingled cattle were intermediates, but even in the commingle pens, steers from the multiple source markets were morbid before their ranch derived pen-mates. The increased risk of morbidity of ranch-derived cattle in commingled pens versus ranch derived cattle in singular pens was consistent with a study by O’Connor et al. (2005). Weanvac (9.5%) and wean (5.9%) had lower morbidity rates than wean (35.1%) and market cattle (41.9%). Market and weaned calves required treatment for BRD before wean45 cattle or weanvac45 calves.

Step et al. (2008) was consistent with the findings of the Roeber et al. (2001) study that showed preconditioned calves had reduced hospital visits than calves purchased at auction markets. These studies give strong implications that allowing cattle the chance to remain on the ranch for at least 30 days after weaning can help increase health and performance. Preconditioning calves also gives them a greater chance of remaining healthy even in commingled pens at the feedlot. This may be because the weaning stage is considered to be a predisposing factor for pneumonia in cattle. Avoiding other stressors near weaning (transporting directly to feedlot for example) may help increase immunity (Lorenz, 2011).

Step et al. (2008), mentioned earlier, showed the importance of the commingling of beef cattle based on origin and morbidity. Bach (2011) conducted an experimental study with Holstein calves to determine the effect weaning and commingling had with
BRD incidence. To experimentally analyze this in dairy calves, Bach (2011) separated 144 female Holstein dairy calves into three categories containing 48 animals grouped in super hutches of 6. The first categorical group consisted of 6 hutches containing 8 animals per hutch that had no previous history of BRD. The second categorical group included 6 super hutches composed of 6 calves without and 2 calves with a previous episode of BRD. The last categorical group included 6 super hutches that housed 5 calves without a history of BRD and 3 calves with previous respiratory afflictions. The study showed that morbidity increased when calves were commingled with others of different health histories. There was a non-significant increase (P=0.10) in new BRD cases of previously unaffected individuals the more the groups were mixed (23.8% in first categorical group with no BRD cases, 30.6% in second categorical group with 2 calves with previous BRD cases, and 43.3% in the final categorical group with 3 calves with previous BRD cases). The odds of acquiring BRD after grouping were 3.89 times greater (P < 0.01) in calves that had previously been affected with BRD. Following the trend in the beef cattle in Step et al. (2008) study, cattle in the homogeneous previously unaffected group had a significantly (P < 0.05) longer mean time from commingling to first incident (22.8 days) than the two heterogeneous groups (10.7 and 10.8) with a 3.3-day standard error.

An earlier study led by Bach (2010) involved 320 female calves where half of the calves were allowed to remain individually housed for an additional 6 days after weaning, and the other half were moved immediately after weaning to a different pen holding 8 calves. Calves who were individually housed an additional 6 days had a significantly
(P<0.01) greater incidence of respiratory ailments (61.2%) in comparison to those who were grouped at weaning (41.4%). However, the living conditions of the individual hutches (1.1 X 1.6 m) were less than ideal for environmental quality and growth conditions because there were no opening for exercise.

**Ventilation**

In addition to ambient temperature and weaning, calf housing ventilation have been linked to respiratory disease risk. Outside individual hutches have been recommended to minimize bacteria air count and disease prevalence (Callan and Garry, 2002). These hutches should be positioned away from exhaust fans and other possible contaminants (Callan and Garry, 2002; Gorden and Plummer, 2010). Although most bacteria in the air is non pathogenic, the presence of bacteria has been suggested to interrupt calf immune function and allow opportunistic pathogens to attack (Gorden and Plummer, 2010). Bacteria counts have been reported to increase with enclosed hutches, bedding type, and smaller pen areas. Bedding and enclosed hutches (additional solid panels) have been implemented to decrease chilling of calves in these environments (Lago et al., 2006; Gorden and Plummer, 2010). Straw bedding has been reported to increase bacterial counts but is still a recommended bedding to decrease the chilling effect on the calf. Dissimilarly, the benefit of added warmth with the addition of additional panels does not outweigh the risk of disease incidence (Lago et al., 2006). Lago et al. (2006) study, with 13 naturally ventilated farms, recommended calve hutches be provided with side panels to avoid nose-to-nose contact but to avoid increased panels in other areas to ensure proper ventilation.
Pathogenesis

The pathogenesis of BRD is complex mainly because of the ubiquitous nature of the etiological agents. Many of the disease-causing organisms are present in the nasal pharynx and upper respiratory tract of healthy cattle. They become important to disease transmission when other factors compromise the immune system of the cattle (Callan and Garry, 2002). Transmission involves many factors including the predisposing stress factors and viral agents that suppress the cattle’s immune system. This suppression allows bacteria to rapidly reproduce in the respiratory tract and then invade the lower respiratory tract (Griffin, 2010).

Environmental factors or viral agents compromise the function of the cattle’s respiratory defense. These defenses include filtration, particle removal, and adhesion resistance. Stressors and viral agents damage the mucous lining of the respiratory system (Ames, 1997). The mucous lining has a constant interaction with internal and external substances and has a filtering system that can remove particles $\geq 5\mu m$ before they reach the alveoli. The mucous itself contains anti-microbial soluble factors and prevents the growth of BRD pathogens (Ames, 1997; Griffin et al., 2010). Viral agents invade this lining and destroy the filtering system by damaging the mucous lining and weakening the production of secretory defense (i.e. lysozomes) and secretory immunoglobins (Ames, 1997; Ellis, 2001). This leads to increased growth of bacterial agents, such as $P.\ haemolytica$ (re-named $Mannheimia\ haemolytica$), in the upper respiratory system (Whiteley et al., 1992). High numbers of bacteria and lack of mucociliary clearance allow
Pathogens to invade the lower respiratory tract, the site of BRD infection (Callan and Garry, 2002).

**Viral Agents in Pathogenesis**

The viral agents of interest are bovine herpes virus 1 (BHV-1), bovine parainfluenza virus type 3 (PI-3), bovine respiratory syncytial virus (BRSV), and bovine viral diarrhea virus (BVDV). They infect the upper respiratory tract and cannot solely cause bacterial pneumonia, but play a crucial role in the disease pathogenesis (Callan and Garry, 2002).

BHV-1 multiplies in mucosal cells and destructs the epithelium of the upper respiratory tract (Wyler et al., 1989). BHV-1 can also cause increased bronchoconstriction, which handicaps the lung defense by aiding in bacteria growth by preventing secretions from exiting the lower airways (Cusack, 2003; Conlon et al., 1987). PI-3 reproduces in the upper and lower respiratory tract in epithelial cells but damages lower respiratory tissue. PI-3 causes bronchitis, bronchiolitis and alveolitis and impairs pulmonary defense. This predisposes cattle to bacterial pneumonia (Bryson, 1985; Cusack et al., 2003). Similar to the other viral agents mentioned, BRSV destroys the ciliated epithelium and the infection of alveolar macrophages reduces cellular immunity. This results in bacterial infection (Cusack et al., 2003). Lesions develop on the lung of cattle, handicapping its performance. Other clinical signs may occur including coughing, fever, depression, and failure to eat (Cusack et al., 2003).
Bacterial Agents in Pathogenesis

The most common bacterial agents in disease transmission are Mannheimia haemolytica (formerly called Pasteurella), Pasteurella multocida, and Haemophilus somnus. However, Mycoplasma spp. can also play a role in pneumonia in cattle, especially calves. These pathogens are usually present in the nasopharynx of animals in the population (Callan and Garry, 2002). Although M. haemolytica (A1 serotype) is commonly credited with being the most common pathogen in BRD (Whiteley et al., 1992), this may be due to the surplus of studies concentrated on shipping fever and the beef industry. Ames (1997) credits Pasteurella multocida as being the most prevalent and important pathogen for pneumonia in dairy cattle.

Both M. haemolytica and P. multocida are gram-negative pathogens that function similarly. The Lipopolysaccharide endotoxin in the outer membrane of their cell wall damages the lung of the cattle. This toxin causes damage that leads to the accumulation of inflammatory cells (Cusack, 2003). The bacteria attract phagocytes to the infected lung and then destroy them with toxins. M. haemolytica impairs phagocytosis and destroys macrophages with a leukotoxin specific for ruminants. M. haemolytica kills neutrophils, while P. multocida inhibits neutrophil function. Consequently, the destruction of phagocytes allows the pathogens to cause damage and in cattle pneumonia the pathology is primarily pulmonary inflammation. (Corbeil and Gogolewski, 1985; Cusack, 2003)

Diagnosis & Clinical Scoring Systems

Bovine Respiratory Disease causes different subclinical and clinical symptoms in cattle. Symptoms include increased respiratory rate, fever, nasal discharge, coughing,
decreased appetite and diarrhea (Van Der Fels-Klerx et al., 2002). Diagnosing BRD can be done with necropsy and diagnostic testing (the gold standard) but it is not a common method used in the field unless an epidemic in a herd is observed. Observing clinical signs to diagnose cattle with BRD has been the most common method; however, there has been some difficulty with consistency. Clinical scoring systems assign values to signs and symptoms and are used for diagnosis in human and veterinary settings because of its simplicity and ease (Love et al., 2014; Massaro and D’Agostino, 2004).

There have been a few clinical scoring systems used to identify BRD. In the beef industry, a DART identification scoring system was used that used depression, appetite, respiration, and temperature as variables for diagnosis. There isn’t much review on this method because it has not been peer-reviewed and has faced criticism due to standardization difficulties (Love et al., 2014). Thomas et al. (1977) was the first score published but it was not widely used because it used 17 predictors not compatible with fieldwork.

Heinrichs (2006) developed a scoring card for respiratory disease uses a 1 to 5-dot system. It evaluates nasal discharge, watery eyes, cough, and rectal temperature when necessary. Unlike other systems, the Heinrichs (2006) method also evaluates the breathing speed of the cattle. One dot is assigned to cattle with normal observation; two dots may be assigned for a slight cough, runny nose, watery eyes, and slow breathing pattern. Three dots are assigned to a more moderate cough, nasal discharge, watery eyes, and rapid panting. Four dots have the same characteristics of 3 but with a more
moderately severe and more frequent cough. A score of 5 is assigned when there is a severe or chronic cough, eye rolls, and mucus discharge from the nose.

University of Wisconsin veterinarians proposed an improved clinical scoring system (McGuirk, 2008). This scoring system used rectal temperature, cough, nasal discharge, eye scores, and ear scores as clinical signs for diagnosis. They scored each sign with a number from 0 to 3. Any cattle with a total score of 4 were heavily monitored but a total score of 5 or greater warranted treatment (McGuirk, 2008).

Recently, Love et al. (2014) improved upon the McGuirk (2008) system, particularly using quantitative tests to assign weights to the clinical signs. The study resulted in 3 different systems that the authors recommended be used based on particular need. The most feasible in dairy settings was BRD 3, which had a 90.2% correct identification percentage. BRD 3 was simple and required less calf handling for identification. The test uses nasal discharge, ocular discharge, ears and head position, cough, and abnormal respiration as the initial signs for diagnosis. If a score of 4 is yielded then rectal temperature is obtained and if temperature is above 102 degrees Fahrenheit then the cattle reaches the 5 total score needed to definitively diagnose the complex. Table 1-1 shows the three scoring systems and the clinical signs used for diagnosis.

**Survivability**

There is concern that BRD has a negative effect on calf survivability. Waltner-Toews et al. (1986) found that morbid animals had increased mortality before calving and later age at calving. More specifically, they concluded that heifers treated for BRD in the first 90 days of life were 2.5 times more likely to die than their counterparts between 90
days of age and calving. Warnick et al. (1994) found that heifers affected with BRD in the first 3 months calved 3 months later than those not affected with BRD.

More recently, Stanton et al. (2012) studied the effect of respiratory disease on calf survivability. Like the Waltner-Toews et al. (1986) and Warnick et al. (1994) studies, BRD cases included only calves who were sick enough to be treated. This study found that 60% of BRD infected cattle survived to first calving in comparison to 84% of those unaffected. They concluded that 36% of the heifers that did not survive to first calving died and 64% were culled; 47% of the deaths were attributed to clinical BRD and 32% of the cullings were due to failure to conceive and poor growth (22%).

**BRD & Performance**

**Body Weight**

There is increasing interest in the effects BRD have on cow performance. Researchers in the dairy industry report that it causes decreased growth (Ames, 1997; Stanton et al., 2012). Virtala et al. (1996) used 410 female dairy calves from 18 commercial farms to determine the impact of diseases on average daily gain (ADG) of heifer calves during the 1st, 2nd, and 3rd months of life. They also used these cattle to determine the effect of disease on total body weight gain during the 3-month period. Virtala et al. (1996) concluded that during the 1st month of life, commercial dairy calves treated for BRD had a reduction in average daily gain (ADG) of 66g. The 2nd month of life showed no significance effect on average daily gain but in the third month, each week of pneumonia reduced ADG by 14 grams. Body weight gain at the end of the 3-month follow up period was only significantly impacted by duration of pneumonia.
Schneider et al (2009) used 5,976 feedlot cattle to determine the effects of BRD. They observed a 0.07±0.01 kg reduction in ADG of cattle treated for BRD. There was an even higher reduction during the early feeding period. More related, Stanton et al. (2012) concluded that cattle treated for BRD 60 days after enrollment into the farm (8 weeks of age at enrollment) weighed significantly (P<0.001) less than the healthy cattle. In particular they weighed 7.1±0.6 kg less at 3 months, 11.4±1.4 kg less at 6 months, and 15.4±1.8 kg less at 9 months.

**Milk Yield**

Inconsistent record keeping for the general population has made it hard to accurately determine the effects BRD has on milk yield, however there are some studies. Stanton et al. (2012) noticed a reduction in test day milk yield but no effect on projected 305-d milk yield. Despite the concern of reduced milk production, many studies have reported no significant differences between treated and healthy cattle (Britney et al., 1984; Warnick et al., 1995). In Svensson and Hultgren’s (2008) Swedish study respiratory disease before 91 days of age was omitted from the final model due to its insignificance as a predictor for 305- day milk yield. Their study used records from 1029 Swedish Reds, 991 Swedish Holsteins and 40 crossbreeds or other breeds. Warnick et al. (1995) collected data from 24 dairy herds near Ithaca, NY from July 1983 to April 1985 and had respiratory disease identified by the persons caring for the animal. They concluded that respiratory disease identified ≤ 90 days of age was not a significant predictor for milk yield.
Schaffer et al. (2016) concluded that pneumonia was significant (P=0.04) in predicting first lactation milk yield. In their study, cattle on a Utah commercial dairy farm from January 1, 2007 to November 11, 2012 were used. Pneumonia was identified as cattle that were infected with BRD ≤ 120 days of age. In the first lactation, 4,005 cows were used to determine a 233±113 kg lower 305-day mature equivalent milk production. This was not the case in lactation 2 where 1717 cows were used to find no associations between BRD and milk yield.

**Genetic Selection**

There has been growing interest to use genetic selection to breed cattle more resistant to BRD. Animal diseases that cause ailments and mortality decrease profitability in animal production. This coupled with consumer fears of antibiotic use to treat morbid animals leave many researchers and producers looking for alternative methods to prevent infection (Snowder, 2006). Snowder (2006) addresses the challenges that arrive when selecting for resistant animals. It is extremely difficult to identify a phenotype for resistant animals. There is also a big misconception that any animal that is healthy is resistant as some animals were never exposed or challenged with infection. Despite the challenges, researchers have been finding ways to use genetics to reduce the incidence of cattle disease, giving confidence that the same can be done with BRD (Van Eenennaam, 2015; Zwald et al., 2004). As early as 1994 selection has been used on the indicator trait somatic cell score (SCS) to reduce the prevalence of mastitis on farms. In 2014, despite the low heritability of SCS (0.12) and the inverse effect selection for low SCS has against
production traits, 7% of the Net Merit Index is still assigned to lowering SCS (Van Eenennaam 2015).

Norwegian Red Cattle have had health traits included in the index since the late 1970s making it a generally healthy breed. A study by Herinstad et al. (2007) did a genetic analysis of respiratory disease in Norwegian Red calves. It was the first genetic study of calf disease based on the Norwegian health recording system. The mean frequency of respiratory disease was lower (0.7%) than previous studies, but this could be largely affected by the fact that the Norwegian cattle have been free from IBR since 1993 (Mork and Hellberg, 2005), free from BVDV since 2005 (Nyberg et al., 2006), and have never seen recordings of Mycoplasma bovis (Lie et al., 2007). Calving difficulty was recorded and calves born under difficult conditions had a greater frequency of respiratory disease than their counterparts (1.08% vs. 0.65%). The disease was also more common in larger herds (1.60% for 30 or more calves vs. 0.54% for less than 10). The herd variable counted for 30% of variance. More promising was the discovery that the lowest ranking sire had a probability of morbidity twice as high as the highest-ranking sire in the study (1.15% vs 0.44%, respectively). This study showed that common health and fitness traits selected for also demonstrated positive trends for overall disease resistance. This implies that more studies should be conducted to aid in BRD genetic selection. Fuerst-Waltl et al. (2010) found a heritability of 0.039 but a higher mean frequency (3.5%) than the Norwegian study. Fuerst-Waltl et al. (2010) used 32,523 female Austrian Fleckvieh heifer calves in their study.
A genetic parameter study by Henderson et al. (2011) used 7,372 Holstein calf records from 36 herds and 264 bulls. BRD had a prevalence of 38.4% and heritability of 0.09 (higher than the previously mentioned studies). The heritability in the Norwegian Red (Heringstad et al. 2008) study used a threshold model while this study used a linear model, which requires dependency on disease incidence. There was an inverse affect between BRD and dairy form (-0.30) and BRD and angularity (-0.42). Angularity is the Canadian trait most equivalent to dairy form. On the other hand, BRD had a desirable Estimated Breeding Value (EBV) correlation (0.15) with daughter pregnancy rate (DPR).

The USDA has funded a 5 year Bovine Respiratory Disease Complex Coordinated Agricultural Project (BRD CAP) whose primary objective is to use genomics to identify less susceptible cattle to BRD. In a study involving cattle from California and New Mexico, 116 genomic regions were significantly associated with the disease. More importantly, several biologically important loci were identified. Genes on Bos Taurus Autosome 15 (PVRL1) and Bos Taurus Autosome 23 (DST) help mediate herpes virus entry into host cells, a gene on Bos Taurus Autosome 14 (AZIN1) is involved in viral susceptibility, and a gene on Bos Taurus Autosome (SLIT3) is associated with inflammation (Neibergs et al., 2014; Van Eenennaam, 2015).

Furthermore, the BRD CAP showed the importance of BRD susceptibility by looking at the sires of the case controls. In the study 707 bulls sired 1,952 calves, where 370 of the bulls had more than one calf. Thirty-four sires had 10 or more calves. Analysis of those 34 sires showed that two sires disproportionately had more offspring as cases (P<0.05). Similarly two sires had significantly more offspring listed as controls (P<0.05). This
shows heritability could be coupled with offspring incidence of disease to help farmers avoid sires who significantly have more sick offspring (Neibergs et al., 2014; Van Eenennaam, 2015).

**Conclusion**

The literature review highlighted the importance of understanding BRD and its negative effects. It’s important to keep conducting studies as treatment and management practices change. Furthermore, there was variation in how BRD was identified and treated, variation in herds, and variation in results. Given this information, our objective was to evaluate the effect of calfhood BRD on survival and future performance in a single herd.
Table 1-1. Clinical criteria for scoring respiratory health in dairy cattle

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Fever (Rectal Temp)</td>
<td>+</td>
<td>+</td>
<td>+</td>
</tr>
<tr>
<td>Nasal Discharge</td>
<td>+</td>
<td>+</td>
<td>+</td>
</tr>
<tr>
<td>Cough</td>
<td>+</td>
<td>+</td>
<td>+</td>
</tr>
<tr>
<td>Eye Score</td>
<td>+</td>
<td>+</td>
<td>+</td>
</tr>
<tr>
<td>Ear Score</td>
<td>+</td>
<td>-</td>
<td>+</td>
</tr>
<tr>
<td>Breathing speed</td>
<td>-</td>
<td>+</td>
<td>-</td>
</tr>
</tbody>
</table>

*- Included in general health evaluation card but not respiratory score
Chapter 2

The Influence of Pneumonia on Short and Long Term Dairy Cattle Survival and Age at First Calving

Abstract

Calfhood pneumonia is associated with decreased survival and delayed age at first calving. These deleterious effects raise economic concerns. The objectives of this study were to evaluate the effect year and season of birth have on calfhood pneumonia and to evaluate the effect early calfhood pneumonia incidence has on calf survival and age at first calving. This study used 1,629 Holstein cattle born between January 2000 and April 2015 on the PSU dairy herd. Health events, cull records, and calving dates were obtained from these cattle. The GLIMMIX and LIFETEST procedures of SAS were used to determine what factors significantly affected pneumonia incidence (n=1629), calf survival (n=1619), calf survival to 24 months (n=1380), and age at first calving (n=1517). Year of birth was a significant predictor for pneumonia incidence (P<0.0001). Cattle born in 2001 (5.43% treated) had 0.112 lesser odds of being treated for pneumonia than cattle born in 2005 (32.99% treated). Season of birth was also a significant predictor for pneumonia incidence (P=0.0003). Calves born in months September to November were most likely to have pneumonia treatment recorded (19.02%). Cattle treated for calfhood pneumonia did not survive in the herd (mean sold age of 1507.91±54.33 days) as long as the calves that were not treated for pneumonia (mean sold age: 1612.49±22.70 days). Birth year (P=0.0054) and pneumonia incidence (P=0.0189) both had significant effects on survival to 24-months of age. Cattle not treated for pneumonia had 1.649 greater odds
of surviving to 24 months than those who were treated for pneumonia. Cattle treated for pneumonia had a slightly older numerical mean for AFC (770.94±7.30 days) than healthy cattle (761.97±2.79 days). This study shows the unfavorable effects pneumonia incidence has on survival and the dire need to control incidence to minimize on farm costs.

**Introduction**

Bovine Respiratory Disease Complex (BRD) is the most important disease in growing cattle based on prevalence and economic cost (Callan and Garry, 2002; Griffin et al., 2010). According to the 2011 National Animal Health Monitoring System (NAHMS) 18.1% of pre-weaned heifers and 11.2% of weaned heifers were infected in 2010 (USDA 2012). The term BRD is most commonly used to describe a host of complex respiratory issues that are present in cattle, including upper respiratory infections and various forms of pneumonia. In the dairy industry many producers use the term ‘pneumonia’ to describe infection (Callan and Garry, 2002; Cusack, 2003).

Studies show that cattle treated for BRD have decreased survival in comparison to their healthy herd-mates (Waltner-Towes et al., 1986; Rossini, 2004). Recently, Bach (2011) concluded that heifers infected with BRD before their first calving had 1.87 lesser odds of completing first lactation. Stanton et al. (2012) reported similar findings in their study that evaluated cattle treated for BRD 60 days after enrollment into the farm (8 weeks of age at enrollment). They concluded that 66% of BRD treated heifers survived to first calving in comparison to 84% of the untreated heifers.
Early age at first calving (AFC), 24 months or less, has been shown to be most economical (Gabler et al., 2000). Unfortunately, BRD has been recorded as negatively affecting AFC (Warnick et al., 1994; Bach, 2011; Stanton et al., 2012). Stanton et al. (2012) reported a median age of 702 days at first calving for healthy cattle and 714 days for BRD infected cattle.

Large potential economic costs for BRD suggest a need for researchers to identify the risk factors of the disease complex and to develop a more comprehensive knowledge of its effects on survivability and AFC. The objectives of this study are to evaluate the effect of year and season of birth on BRD during the first six months of life and the effect of early calf-hood BRD incidence on survival and AFC.

**Material and Methods**

**Data Source**

Health events, cull records, and calving dates were obtained from Holstein cattle from the Pennsylvania State University (PSU) dairy herd. Health treatments are entered into Dairy Comp 305 (Valley Agricultural software, Tulare, CA) by herd management personnel at Penn State. These health records were retrieved from Dairy Comp 305 to identify calves that had been treated. Only cattle born between January 2000 and April 2015 were included in the study. This yielded an initial population of 1629 cattle of which 245 were treated for pneumonia within the first 180 days of life. Analyses were conducted to determine the influence of year and season of birth on pneumonia incidence, the influence of pneumonia on survival, and the influence of pneumonia on AFC. Table 2-1
summarizes the cattle population for each analysis. Bovine Respiratory cases for this study were defined as cattle that were treated for “pneumonia”, so the words pneumonia and BRD are used interchangeably in this paper. Season of birth was defined as winter (December through February), spring (March through May), summer (June through August), and fall (September through November).

**Statistical Analyses**

**Year and season of birth on pneumonia.**

The effect of year and season of birth on pneumonia incidence was evaluated using the GLIMMIX procedure of SAS (v 9.4; SAS Institute, Inc., Cary, NC). Pneumonia, the binomial dependent variable, was determined by the fixed effects year and season of birth. The interaction of year and season of birth was considered as a random effect but did not converge so it was omitted from the generalized linear mixed model. All 1629 cattle observations, 245 of which were treated for pneumonia, were used to generate the model.

**Pneumonia on survival**

A longitudinal survival analysis was conducted in SAS (v.9.4; SAS Institute, Inc., Cary, NC) using the LIFETEST procedure. In this survival analysis survival probability analyzed pneumonia’s (1= treated for pneumonia; 0=not treated) influence on sold age in days. Ten observations were omitted due to unrecorded or uncertain cull dates. This yielded a population of 1619 animals of which 1376 were BRD free and 243 were treated for pneumonia. In this analysis, 28.41 percent of the cattle (n=460) had not been culled
and were considered censored observations. Rank tests were generated to determine short
(Wilcoxon) and long-term (Log-Rank) effects of pneumonia on herd survival.

**Pneumonia-year of birth on survival to 24 months**

The survival analysis only considered the influence of pneumonia on survival. It is plausible that other herd dynamics such as season of birth could influence both survival and pneumonia and lead to biased results if not jointly considered. Therefore, survival to 24 months (1 = survived; 0 = not survived) was evaluated as a binary dependent response variable with pneumonia incidence, year of birth and season of birth tested as fixed independent effects using the GLIMMIX procedure of SAS (v.9.4; SAS Institute, Inc., Cary, NC). Season of birth was removed from the final model because it was not significant. The interaction of year and season of birth was analyzed as a random effect to the general linear mixed model but omitted because it failed to converge. In this analysis, 263 of the cattle were still heifers at time of data retrieval and were omitted leaving a population size of 1380 cattle where 220 were treated for pneumonia.

**Pneumonia on age at first calving (AFC)**

A second longitudinal survival analysis was conducted in SAS (v.9.4; SAS Institute, Inc., Cary, NC) using the LIFETEST procedure. Survival probability was used to analyze pneumonia’s (1 = treated for pneumonia; 0 = not treated) influence on age at first calving in days. Prior to the analysis, 16 cattle records were omitted from the original data set because the heifers were induced into first lactation (Macrina et al., 2011), 96 other cattle were omitted from the study due to calving data entry errors
realized by unrealistic AFC (n=52) and missing values for AFC (n=44). This yielded a
population of 1517 records where 234 were BRD cases and the other 1283 were
considered healthy in regards to BRD. Young-stock that had not yet calved (29.47%)
were censored observations in the study. Rank tests were generated to determine short
(Wilcoxon) and long term (Log-Rank) effects of pneumonia on AFC.

Results

Pneumonia

Year of birth was a significant predictor for pneumonia incidence (P<0.0001); cattle born in 2005 (32.99% treated) and 2003 (29.21% treated) had a greater occurrence of BRD treatment than cattle born in the other years. Cattle born in 2001 (5.43% treated) had 0.112 lesser odds of being treated for pneumonia than cattle born in 2005. Season of birth was also a significant predictor for pneumonia incidence (P=0.0003). Calves born in months September to November were most likely to have pneumonia treatment recorded (19.02%), followed by calves born in December to February (18.34%), July to August (11.75%), and March to June (8.93%). Accordingly, calves born in March to June had 0.434 lesser odds of being treated for pneumonia than those born in September to November. Odds ratios for season of birth are presented in Table 2-2. When cattle left the herd in the first 365 days of life, 68.81% left because of death with similar percentages for those treated for pneumonia (65.38%) and those who were not (69.88%). However, only 4.19% of non-treated cattle died in the first year versus 6.94% of those who were treated.
**Survivability**

Figure 2-1 shows a survival curve of 1619 cattle. Cattle treated for pneumonia had a mean sold age of 1507.91 days with a standard error of 54.33 and cattle not treated for pneumonia had a mean sold age of 1612.49 days with a standard error of 22.70. The Wilcoxon test trended toward significance (P=0.0506), but the Log-Rank test was not (P=0.1866). This indicated that pneumonia had a larger effect in the short term, so further exploration was needed to determine the difference of the two tests. Only 90.51% of cattle with pneumonia survived to 180 days versus 95.07% of cattle without pneumonia. However, by 1460 days, 55.00% of pneumonia cattle survived in comparison to 58.85% of those without.

Birth year (P=0.0054) and pneumonia incidence (P=0.0189) both had significant effects on survival to 24-months of age. Season of birth was not a significant variable for survival to 24 months (P=0.7919). Cattle not treated for pneumonia had 1.649 greater odds of surviving to 24 months than those who were treated for pneumonia.

**AFC**

Figure 2-2 shows the probability of AFC in days according to pneumonia stratum. Neither the Wilcoxon test (P=0.4644) nor the Log-Rank test (P=0.2220) was significant. The mean average of AFC for cattle treated for pneumonia was 770.94 days with a standard error of 7.30 while those not treated for pneumonia had a mean of 761.97 with a standard error of 2.79.
Discussion

Calves born during fall (September through October) and winter (December through February) had significantly greater odds of being treated for pneumonia. This data showed that cattle born in the months with the coldest temperatures and most varied temperatures had greater chances of being treated for BRD and is consistent with papers that state BRD incidence is higher in autumn and early winter months (MacVean et al., 1986; Cusack, 2003; Taylor et al., 2010). MacVean et al., (1986) reported a mean BRD incidence rate of 15.0±9.4 per 10,000 cattle in the fall of 1982, 2.0±2.4 in the spring of 1983, and 3.0±3.0 in the fall of 1983 on a feeder company feedlot. The MacVean et al. (1986) varies from our present study because the breed and sex of the cattle was not known or considered in their study. Furthermore, cattle entered the feedlot at 6 months and had pneumonia incidence reports on 5 different intervals after arrival (0 to 7 days, 8 to 15 days, 16 to 30 days, 31 to 60 days, and >61). Our study analyzed calf-hood pneumonia within the first 6 months of life.

There is debate whether extreme temperatures or sudden changes in temperature are the reason for increased incidence. Callan and Garry (2002) credit both rapidly changing environments and extreme temperatures as risk factors for disease transmission. The current study did not contrast the effects of absolute temperature versus temperature change, but highlights that calves born during fall and winter are at elevated risk of developing BRD. More importantly, the PSU dairy barn uses natural ventilation, which poses its own risk for disease incidence. Natural ventilation systems often have
compromised air hygiene and can potentially become a source of pathogenic and non-pathogenic airborne bacteria (Lago et al., 2006).

The survival analysis for age when a calf was sold or died (Figure 2-1) shows reduced survivability for cattle treated for pneumonia in the first 180 days of life. Reduced cattle survivability was consistent with published literature (Bach, 2011; Stanton et al., 2012). Particularly, Bach (2011) discovered that cattle who had 4 or more cases of BRD had 1.87 lesser odds of completing first lactation than those who had no incidence of BRD before calving. Those who were treated for pneumonia in the present study had 1.649 lesser odds of remaining in the herd to 24 months. The present study evaluated cattle that were treated for pneumonia versus those who were not, without taking into consideration the number of times the calves were treated.

Studies have shown that cows that calve by 730 days are a better economical option than their peers because of reduced feed costs (Gabler et al., 2000; Heinrichs and Heinchs, 2011). Thus, we examined the role pneumonia played on AFC. The survival analysis visually showed no difference between the curves. The Wilcoxon and Log-Rank tests were both insignificant. This implied that there were no significant differences, either long term or short term, of age at first calving between cattle treated for pneumonia during the first 180 days of life and those who were not treated. The Waltner-Towes et al. (1986) study showed no delayed calving age for pneumonia cattle. This is, however, inconsistent with Warnick et al. (1994) who concluded that cattle with BRD calved 3 months later than their healthy peers. The differences in the previous study (Warnick et al., 1994) and the current study can be due to the differences in identification of BRD
cases. BRD cases were identified by signs in the previous, but cattle had to be treated for pneumonia in order to be included in this study. Using the Warnick et al. (1994) case identification method could increase the sensitivity of our study but reduce the specificity. Bach (2011) study showed a delay in AFC as the number of treatments for BRD increased. Again, number of treatments was not evaluated in the present study. Bach (2011) also considered documented BRD treatments up to first calving whereas we evaluated BRD in the first 6 months of life.

**Conclusion**

Our dataset allowed us to examine records for 16 years from the same herd, which removed across-farm variation from the analysis. We noted a significant seasonal effect on pneumonia incidence. Heifers born during fall and winter months were treated for pneumonia significantly more often than their counterparts, highlighting the need to ensure that calves born during colder months are provided adequate shelter and ventilation. Heifers treated for pneumonia were culled earlier than their healthy peers and were significantly less likely to survive to 24 months, but did not have an extended AFC in this herd. Transitional cow health could have been a possible confounding variable so correlation should be considered in future studies. This study showed, using this institutional farm, that even in modern management systems there is a need to control pneumonia incidence because it is affecting survival, and thus economic costs due to treatment and replacement heifer costs.
**Table 2-1.** The number of animals included in each analysis, the number and percentage treated for pneumonia, and the percent of observations censored

<table>
<thead>
<tr>
<th>Analysis</th>
<th>Observations</th>
<th>Treated</th>
<th>% Treated</th>
<th>Censored</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pneumonia incidence by year and season of birth</td>
<td>1629</td>
<td>245</td>
<td>15.04%</td>
<td>-</td>
</tr>
<tr>
<td>Survival analysis of age when sold or died</td>
<td>1619</td>
<td>243</td>
<td>15.01%</td>
<td>28.41%</td>
</tr>
<tr>
<td>Survival to 24 months</td>
<td>1380</td>
<td>220</td>
<td>15.94%</td>
<td>-</td>
</tr>
<tr>
<td>Survival analysis of AFC</td>
<td>1517</td>
<td>234</td>
<td>15.43%</td>
<td>29.47%</td>
</tr>
</tbody>
</table>
Table 2-2. Odds of pneumonia incidence based on season of birth

<table>
<thead>
<tr>
<th>Season</th>
<th>Comparative Season</th>
<th>Odds Ratio</th>
</tr>
</thead>
<tbody>
<tr>
<td>Winter</td>
<td>Spring</td>
<td>*2.221</td>
</tr>
<tr>
<td>Winter</td>
<td>Summer</td>
<td>*1.669</td>
</tr>
<tr>
<td>Winter</td>
<td>Fall</td>
<td>0.963</td>
</tr>
<tr>
<td>Spring</td>
<td>Summer</td>
<td>0.752</td>
</tr>
<tr>
<td>Spring</td>
<td>Fall</td>
<td>*0.434</td>
</tr>
<tr>
<td>Summer</td>
<td>Fall</td>
<td>*0.577</td>
</tr>
</tbody>
</table>

*P<0.05
Figure 2-1. The probability of survival to age in days according to BRD incidence in the first 60 days of life.\(^1\)
\(^1\) + = Censored observations; animals that did not have pneumonia are in blue; animals with pneumonia are in red.
Figure 2-2. The probability of calving age in days according to BRD incidence in the first 60 days of life.\textsuperscript{1}

\textsuperscript{1} + = Censored observations; animals that did not have pneumonia are in blue; animals with pneumonia are in red.
Abstract
Calfhood pneumonia has been a suggested link to future cow performance; namely, milk yield and body weight. This raises economic concerns for dairy producers who must decide if raising a diseased calf is economically justifiable. The objective of this study was to analyze the effect, if any, pneumonia has on the milk yield and body weight of 1055 Holstein cattle from the Penn State University (PSU) dairy herd. The health events of the cattle were obtained along with 708,162 daily milk yield observations and 560,059 daily body weight observations. The data was analyzed using a mixed model in ASREML where yields were determined by the fixed effects (lactation, week of lactation within lactation group, pneumonia status, pneumonia status within lactation group, pneumonia status within week of lactation and lactation group, and age group) and random effects (year-week within lactation group, cow, cow within lactation, and residual error). For milk yield, the effect of pneumonia (P=0.941) was not significant across lactations and stage of lactation. Analysis of lactation curves reported that the weeks showing significant differences in milk yield between diseased and healthy cattle tended to occur in late lactation. Also, the number of weeks that showed significant differences in milk yield steadily increased from lactation 1 to lactation 3. Pneumonia (P=0.332) was not a significant indicator of body weight across lactations and stage of lactation. The
effects of calfhood pneumonia on milk yield and body weight were subtle and not significant across lactations.

**Introduction**

Calfhood Bovine Respiratory Disease (BRD) has been linked to future cow performance (Britney et al., 1984). Researchers in the dairy industry report that it causes decreased growth (Ames, 1997; Stanton et al., 2012). Virtala et al. (1996) concluded that during the 1st month of life, commercial dairy calves treated for BRD had a reduction in average daily gain (ADG) of 66g. Inconsistent record keeping has made it hard to accurately determine the effects BRD has on milk yield. Stanton et al. (2012) noticed a reduction in first test day milk yield but no effect on projected 305-d milk yield. Despite the concern of reduced milk production, many studies have reported no significant differences between treated and healthy cattle (Britney et al., 1984; Warnick et al., 1995).

Effects on growth and milk production raise economic concerns for dairy producers who must decide if raising a diseased calf is economically justified despite possible decreased future performance. The objective of this study is to analyze the effect of BRD on lactating dairy cow milk yield and body weight of lactating dairy cows.

**Materials and Method**

*Data Source*

Health events, milk records, and weights, were obtained from Holstein cattle from the Pennsylvania State University (PSU) dairy herd. Health treatments were recorded using
the same protocol from the previous chapter, the health records were retrieved from Dairy Comp 305 to identify calves that had been treated. Daily milk and body weight records were retrieved from AfiFarm software (Kibbutz Afikim, Israel). Bovine Respiratory (BRD) cases for this study were defined as calves that were treated for “pneumonia” in the first six months of life, so the words pneumonia and BRD are used interchangeably henceforth. Only cattle born between January 2000 and April 2015 were included in the study. The data for this retrospective study was extracted in March 2015. Unrealistic cow records were omitted from this study; this included records that lacked cow milk data or records of cows who reported less than 5 kg of milk, unrealistic age at first calving (<600 days) records, and records of cows who remained in days in milk > 365 days. This yielded an initial population of 1055 cattle with 708,162 daily milk yield observations where 286,222 of the observations were in lactation 1, 208,375 observations in lactation 2, and 208,390 observations in lactations ≥3. There were 560,059 daily body weight observations, 22,445 of which were in lactation 1, 169,687 observations in lactation 2, and 165,927 observations in lactations ≥3. Daily milk and body weight records were retrieved from AfiFarm software (Kibbutz Afikim, Israel).

Statistical analysis

The data was analyzed using a mixed linear model in ASREML (Gilmour et al., 2006). The model is provided below.

\[ y_{ijklmnop} = Lact_i + WOL_j(LG_k) + P_l + P_l(LG_k) + P_l(WOL_j \ast LG_k) + AG_m + YW_n(LG_k) + Cow_o + Cow_o(Lact_i) + \varepsilon_{ijklmnop} \]
In this model, trait y (either daily milk yield or daily BW) is determined by the fixed
effects of lactation (Lact) i, week of lactation (WOL) j within lactation group (LG;
lactation 1, 2, and ≥3) k, pneumonia status (P) l, P l within LG k, P l within WOL j and
LG k, and age group (AG; bimonthly age at calving) m. Random effects were year-week
(YW) n within LG k, Cow o, Cow o within Lact i, and residual error (ε). Predicted values
were generated for body weight and milk yield.

**Results**

**Milk yield**

The effect of pneumonia (P=0.941) was not significant across lactations and stage
of lactation. Predicted milk yields for lactation groups 1, 2 and ≥3 are presented in Table
3-1. In Lactation 1, cows treated for pneumonia as a calf yielded 32.26 kg of milk while
those that did not have pneumonia as a calf yielded 32.75 kg (P=0.42). Similarly in
lactation 2, cattle treated for pneumonia as a calf yielded 34.89 kg of milk versus 35.43
kg from healthy individuals, but no significant differences (P=0.47). However, in
lactation ≥3 there was a trend toward significance; cows treated for pneumonia as a calf
yielded 38.45 kg of milk in comparison to 37.09 kg from healthy cattle (P=0.07). The
change from lower yield in lactations 1 and 2 to higher in ≥3 lactation resulted in a trend
toward significance for pneumonia within lactation group (P=0.052).

Figures 3-1, 3-2, and 3-3 graphically show the differences in pneumonia-treated
and healthy cattle in regards to milk yield by week in lactation during lactations 1, 2 and
≥3, respectively. The weeks showing significant differences in milk yield between
diseased and healthy cattle tended to occur in late lactation. Also, the number of weeks
that showed significant differences in milk yield between health conditions steadily increased from lactation 1 to lactation 3. In lactation 1 there were 4 weeks that showed significant differences; the largest difference was a 2.13-kg/d difference in favor of healthy cattle during week 52. In lactation 2, there were 9 weeks that showed significant differences in milk yield with the largest difference (2.61 kg) occurring in week 50 in favor of healthy cattle. Lactation 3 had 15 weeks that showed significant differences, the largest difference occurred in week 40 where those that had pneumonia as calves outperformed healthy cattle by 3.12 kg.

**Body Weight**

Pneumonia (P=0.332) and pneumonia within lactation group (P=0.360) were not significant indicators for body weight. Predicted body weights are presented by lactation group and health status in Table 3-1. Cows treated for calfhood pneumonia weighed (571.14 kg) significantly the same as healthy cattle (574.13 kg) in lactation 1 (P=0.54). In lactation 2, cows treated for pneumonia also weighed 644.94 kg while healthy cattle weighed 653.69 kg, which was not significantly different (P=0.11). Equivalently in lactation 3, although not significant (P=0.68), cows treated for calfhood pneumonia weighed less 695.87 kg and cows not treated for pneumonia weighed 698.18 kg.

Figures 3-4, 3-5, and 3-6 show the differences in pneumonia and healthy cattle predicted body weights by week in lactation during lactations 1, 2 and ≥ 3, respectively. The weeks that showed significant differences in weight and many of the weeks that trended toward significant in lactation 1 occurred early in lactation. Specifically, week 1
had the largest difference (10.48 kg) between predicted body weights of the cows treated for calfhood pneumonia and those not treated favoring the latter. In lactation 2 the largest difference (12.72 kg) between predicted body weights occurred during week 34. There were no weeks in lactation 3 that showed significant differences, however the largest difference (10.24 kg) occurred in week 52 (P=0.098).

**Discussion**

While there were small numerical differences in future milk yield between pneumonia treated and healthy calves, particularly in later lactation, the differences were not significant. Much like the present study, pneumonia was not a significant predictor for milk yield in other literature (Britney et al., 1984; Svensson and Hultgren, 2008). In Svensson and Hultgren’s (2008) Swedish study respiratory disease before 91 days of age was omitted from the final model due to its insignificance as a predictor for 305-day milk yield.

Similar to the present study, Warnick et al. (1995) had respiratory disease identified by the persons caring for the animal. They concluded that respiratory disease identified ≤ 90 days of age was not a significant predictor for milk yield.

Unlike the present study, Schaffer et al. (2016) concluded that pneumonia was significant (P=0.04) in predicting first lactation milk yield. In their study pneumonia was identified as cattle that were infected with BRD ≤ 120 days of age. In the first lactation 4,005 cows were used to determine a 233±113 kg lower 305-day mature equivalent milk production. This was not the case in lactation 2 where 1717 cows were used to find no
associations between BRD and milk yield. Although the current study had a lot of daily data, we had a moderate number of animals in comparison to the Schaffter et al. (2016) study that had almost 3.8 times more animals. Heinrichs and Heinrichs (2011) also concluded that calf health, scours and cough, had a significant negative effect on first lactation 305-day mature equivalent production and actual milk.

In early weeks of lactation 1, cows treated for pneumonia as calves weighed less but they caught up to their herd-mates by week 22. Generally, cattle treated for pneumonia weighed less than their healthy herd mates across all lactations, but the effects were not significant. In lactation 1 there was a 2.99 kg difference; there was an 8.75 kg difference in lactation 2; and a 2.31 kg difference in lactations ≥3. Other papers state that animals affected with pneumonia experience a reduced body weight gain (Virtala et al., 1996; Ames, 1997; Stanton et al., 2012).

Virtala et al. (1996) used 410 female dairy calves from 18 commercial farms to determine the impact of diseases on average daily gain (ADG) of heifer calves during the first, second, and third months of life. They also used these cattle to determine the effect of disease on total body weight gain during the 3-month period. Calves were selected in this study during January 1, 1990 and December 31, 1990. Clinicians selected the new calves each month in birth order that were alive during the first visit of that month. Each calf was followed for 3 months and was checked weekly. Pneumonia was diagnosed using clinical signs. The study concluded that incidence of pneumonia that required treatment reduced body weight gain by 66 grams in the first month. The 2nd month of life showed no significance effect on average daily gain but in the third month, each week of
pneumonia reduced ADG by 14 grams. Body weight gain at the end of the 3-month follow up period was only significantly impacted by duration of pneumonia. The present study did not study the duration of infection.

Schneider et al. (2009) used 5,976 feedlot cattle to determine the effects of BRD. They observed a 0.07±0.01 kg reduction in ADG of cattle treated for BRD. There was an even higher reduction during the early feeding period. More related, Stanton et al. (2012) concluded that cattle treated for BRD 60 days after enrollment into the farm (8 weeks of age at enrollment) weighed significantly (P<0.001) less than the healthy cattle. In particular they weighed 7.1±0.6 kg less at 3 months, 11.4±1.4 kg less at 6 months, and 15.4±1.8 kg less at 9 months. Virtala et al. (1996) and Schneider et al. (2009) observed immediate effects of pneumonia; the present study evaluated the effects that occurred 1.5 years or more after treatment.

We reported in Chapter 2 of this study that calf-hood pneumonia had an influence on survival and removal of diseased calves from the herd prior to first calving. This potentially biased our estimates of the long term effects on milk yield and body weight. Culled heifers could have potentially been significantly under-producing animals if they had survived to lactation. Culling those animals before production could have handicapped our ability to examine the effects the disease had on performance.

**Conclusions**

Our study allowed us to take a retrospective observation of pneumonia’s effect on dairy cattle performance. We concluded that the effects of calf-hood pneumonia on milk
yield and body weight were subtle and not significant within and across lactations. Calves with pneumonia did calve at a lower BW (10.48 kg less in week 1 of first lactation), but the effect did not last through lactation. However, we previously documented (Chapter 2) that calf-hood pneumonia had an influence on survival and removal of diseased calves from the herd prior to first calving may have biased our estimates of the long term effects on milk yield and body weight.
Table 3-1. Milk yield and body weight in kilograms based on pneumonia incidence

<table>
<thead>
<tr>
<th>Lact</th>
<th>Milk yield ± s.e</th>
<th>SED</th>
<th>Body Weight ± s.e</th>
<th>SED</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>No Pneumonia</td>
<td>Pneumonia</td>
<td>No Pneumonia</td>
<td>Pneumonia</td>
</tr>
<tr>
<td>1</td>
<td>32.75±0.45</td>
<td>32.26±0.68</td>
<td>0.61</td>
<td>574.13±3.22</td>
</tr>
<tr>
<td>2</td>
<td>35.43±0.72</td>
<td>34.89±0.98</td>
<td>0.73</td>
<td>653.69±4.62</td>
</tr>
<tr>
<td>3</td>
<td>37.09±0.88</td>
<td>38.45±1.09</td>
<td>0.75</td>
<td>698.18±5.43</td>
</tr>
</tbody>
</table>

SED = standard error of differences
Figure 3-1. Lactation 1 milk yield in kilograms versus week of lactation for pneumonia and healthy cattle

*=P<0.05
+= P<0.10
Figure 3-2. Lactation 2 milk yield in kilograms versus week of lactation for pneumonia and healthy cattle

*=P<0.05
+= P<0.10
Figure 3-3. Lactation 3 milk yield in kilograms versus week of lactation for pneumonia and healthy cattle.

*=P<0.05
+= P<0.10
Figure 3-4. Lactation 1 body weight in kilograms versus week of lactation for pneumonia and healthy cattle

* = P<0.05
+= P<0.10
Figure 3-5. Lactation 2 body weight in kilograms versus week of lactation for pneumonia and healthy cattle

*=P<0.05

+=P<0.10
Figure 3-6. Lactation 3 body weight in kilograms versus week of lactation for pneumonia and healthy cattle

*=P<0.05
+= P<0.10
Chapter 4
Summary and Conclusions

Pneumonia incidence and its effects were investigated on dairy cattle in this study. Analysis of pneumonia incidence was evaluated using 16 years of records from the same herd (PSU dairy herd), removing across-farm variation from the analysis. There were significant year and seasonal effects on pneumonia incidence. Investigation of the seasonal effect showed that heifers born during fall and winter months were treated for pneumonia significantly more often than their counterparts, highlighting the need to ensure that calves born during colder months and months with highly variable climates are provided adequate shelter, ventilation, and a high plane of nutrition.

Heifers treated for pneumonia were culled earlier than their healthy peers and were significantly less likely to survive to 24 months, but did not have an extended AFC in this herd. Additionally, cattle treated for pneumonia as calves had numerically subtle but mostly non-significant effects within and across lactations for daily milk yield and body weight. Calves with pneumonia did calve at a lower BW (10.48 kg less in week 1 of first lactation), but the effect did not last through lactation. However, the influence pneumonia had on survival and removal of diseased calves from the herd prior to first calving may have biased our estimates of the long-term effects on performance.

This study shows that even on an average Pennsylvania farm, there is a need to control pneumonia incidence because it is significantly affecting survival and thus potentially increasing economic costs due to treatment and replacement heifer costs. Future studies should experimentally analyze the effects of pneumonia so that diseased
animals are not culled and their performance can more effectively be compared to the performance of their healthy herd mates. More investigation can be done to determine the effect of early therapy on repeated infection. Furthermore, repeated incidence and number of treatments should be evaluated simultaneously with healthy animals to more accurately report economic costs for repeated infection. Nevertheless, this study confirms that calfhood BRD (pneumonia) is still a concern on dairy farms; proper care of calves from birth through weaning and the critical few months after weaning are necessary to reduce the likelihood of pneumonia.
References:


