Investigating health abnormalities of calves arriving at a veal facility and their association with mortality, morbidity, and growth

by
Kayla J. Scott

A Thesis
presented to
The University of Guelph

In partial fulfillment of requirements
for the degree of
Master of Science
in
Population Medicine

Guelph, Ontario, Canada
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ABSTRACT

INVESTIGATING HEALTH ABNORMALITIES OF CALVES ARRIVING AT A VEAL FACILITY AND THEIR ASSOCIATION WITH MORTALITY, MORBIDITY, AND GROWTH

Kayla J. Scott.
University of Guelph, 2018

Co-Advisors: Dr David F. Kelton
Dr David L. Renaud

This thesis is an investigation of health abnormalities within grain-fed veal calves as they are arriving at a rearing facility in Southern Ontario. A prospective cohort study was used to assess the health status of the calves at arrival to observe the associations of health abnormalities with morbidity, mortality, and average daily gain.

Many calves entered the veal facility with a health abnormality and most of the morbidity occurred in the first three weeks following arrival. There were several associations with calf morbidity; low body mass index, increased rectal temperature, and season were all associated with increased calf morbidity. Body mass index was associated with morbidity within the first 21 days of arrival at the veal rearing facility. Rectal temperature and season of arrival were associated with overall calf morbidity throughout the growing period. There were many associations with mortality including fecal score and body mass index. A higher body mass index was associated with lower mortality.

Calves were weighed at arrival and their weights were tracked throughout the growing period. Within the first 7 weeks at the facility body mass index was associated with higher average daily gain. In the last 4 weeks of the calves being under observation for 11 weeks, rectal temperature between 38.6-38.7°C was associated with higher average daily gain. Calves that arrived in the spring and autumn months were associated with a lower average daily gain. Throughout the entire 11 week growing period at this facility, higher body mass index on arrival and rectal temperature between 38.6-38.7°C were associated with higher average daily gain.
ACKNOWLEDGMENTS

This has been an enjoyable and inspiring process that I am so thankful that I’ve had the opportunity to participate in. There are many people to thank for all of their contributions to helping me complete this thesis. I would not have gotten it done without help from my committee: Dr. David Renaud, Dr. David Kelton, and Dr. Todd Duffield. Dave R., thank you for your endless guidance and support throughout my entire project. You were always available for questions regarding the project, stats or edits. You always managed to push me to think outside of the box and allow me to learn new things along the way. Dave K., thank you for the opportunity to complete this thesis and all of your guidance along the way. You’ve always been in my corner for encouragement, advisement and mentorship throughout this degree. Todd, thank you for all you help during committee meetings and bringing a positive attitude and perspective to the project. This committee provided such a diverse selection of knowledge and expertise throughout the course of this project and their devotion and guidance has been greatly appreciated. All of you motivated me to think about all aspects of the project and were always excited to hear about what was going on.

There were many students that helped me accomplish this project. I would like to thank Victoria, Larissa, Angela, and Taylor for your help during the long days on farm screening calves. It would not have happened without you. Thanks to all the graduate students for chats about projects, venting when necessary, and making sure we all had a blast and supported one another at conferences. A huge thank you to Aaron Keunen and all of the staff at Mapleview Agri Ltd., you made the entire process of data collection very smooth.

Sincere acknowledgements also go to the Veal Farmers of Ontario, Dairy Farmers of Ontario, and the Ontario Ministry of Agriculture, Food and Rural Affairs. All these sources were fundamental in providing resources and time to the completion of this thesis.

I would also like to thank my family and friends. To my amazing husband, Cody, thank you for all of your encouragement throughout this project and always inspiring me to follow through with my projects. Your endless love and support is everything to me. To my mom; thank you for all of your support, countless dinners, and phone calls. To my in-laws, the Walker family, thank you for always taking an interest in what was going on in the project, including helping me come up with inventive ways to put data loggers in difficult places. You always ensured that I step back and think about the study from a producer’s perspective. To my friends,
thank you for always having a listening ear and bringing an outside perspective to the project. There truly are no words to describe how grateful I am to have had such undivided support from these people who are so close to my heart! You all have contributed more than you can imagine along the way in the completion of this thesis! Dr. Ken Leslie, thank you for all of your support throughout my 4-H, undergraduate, and graduate career. You are the major reason I decided to pursue a graduate degree and I cannot thank you enough as this experience has been unforgettable. The impact you’ve had on the dairy industry and your focus in calves was inspiring.
STATEMENT OF WORK DONE

Preparation of this thesis was completed by Kayla Scott in its entirety. This included study design, data collection, statistical analysis, interpretation, writing and preparation of manuscripts. Todd Duffield, David Kelton, and David Renaud advised on study design, statistical analysis and provided edits on all chapters. Funding was prepared by Veal Farmers of Ontario, Dairy Farmers of Ontario, and the Ontario Ministry of Agriculture, Food and Rural Affairs.
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LIST OF ABBREVIATIONS

95% CI: 95% confidence interval
ADG: average daily gain
AMR: antimicrobial resistance
BCS: body condition score
BMI: body mass index
BRD: bovine respiratory disease
CAHI: Canadian Animal Health Institute
CDC: Centers for Disease Control and Prevention
ETEC: enterotoxigenic *Escherichia coli*
FPT: failure of passive transfer
IgG: immunoglobulin G
n: number of calves or samples tested
OR: odds ratio
P: p-value
STP: serum total protein
THI: temperature humidity index
CHAPTER 1: LITERATURE REVIEW

Transportation

Within North America, the majority of livestock are transported at some point during their production cycle (Knowles, 1995). There has been an increasing concern in the way that livestock is transported and for the well-being of the animals during the haul (Knowles & Warriss, 2007). The transportation of livestock is not simply confined to bovine, swine and poultry are also transported often. Transportation has been noted to be the most stressful event for swine prior to slaughter, resulting in fatigue, injury, poor meat quality, or mortality (Bench et al., 2008; Geverink et al. 1998). Poultry meat quality has been correlated with transportation and the travelling distance, duration, stocking density, and microclimate within the trailer (Schwartzkopf-Genswein et al. 2012). The transport of young calves is also considered a very stressful event. Loading, unloading, mixing with unfamiliar animals, and different management styles are all associated with increased stress (Trunkfield and Bloom, 1990).

There are various indicators suggesting that transportation has a negative effect on young calves. It has been suggested that the age at which calves are transported could be an indicator to how well calves tolerate transportation stress. Knowles et al., (1995) recommended that calves should be transported at a minimum of 4 weeks of age to reduce the negative impact of transit. Depending on the length of the journey and time of year the calves will experience mild to severe dehydration (Atkinson, 1992). Implying that the climate that the calves are exposed to will negatively impact them as well. Unlike smaller livestock, calves generally do not lie down while being transported so sufficient stocking density is also essential. High and low stocking densities during transport have been noted as poor welfare for the livestock industry (Knowles, 1999). Many factors contribute to the creation of the ideal environment for transporting young calves.

Calves entering the veal industry are often transported many times before they reach their final destination. These calves are transported from their dairy farm of origin to the veal rearing facility, however in some cases, there may be various stops at other dairy farms or auction marts. Transportation can be a source of major stress to young calves in particular, due to increased handling, deprivation of feed and water, mixing of unfamiliar animals, as well as the climate the animals experience for the duration of the haul (Fisher et al. 2009; Taylor et al., 2010). Cave et
al. (2005) found that mortality exponentially increases with distance travelled. Trailer design and microclimate must be observed to determine if they are contributing factors.

Due to the growing size of farms and location of various facilities; transport of livestock is a common and convenient way of moving animals from one place to another. However, it is the way in which the animals and transportation is managed that can negatively impact the livestock, creating a welfare concern (Fisher et al., 2009).

**Stress**

The term ‘stress’ is used broadly in biology, no concrete definition of stress has been established. Unlike most pathogens, stress has no defined aetiology or prognosis (Moberg, 2001). Intuitive feelings about stress often guide our use of the term (Moberg, 2001). Like humans, while experiencing severe stress, animals are more likely to disease or fail to reproduce or develop properly (Moberg, 1985). Stress diverts the animal’s resources impairing other biological functions such as growth and immune function (Moberg, 2000). It is recognition of these harmful effects of stress that has allowed us to the importance of stress to an animal’s welfare, or well-being.

Aside from the actual transport, loading, unloading, and mixing with other livestock can create stress (Knowles, 1995). Animals entering new environments such as the trailer, new barns, or interacting with new populations creates unfamiliarity resulting in stress. Handling, unusual or unique interaction, and transportation are considered as major stressors for livestock (Grandin, 1997; Knowles and Warriss, 2000); impacting health, well-being, performance, and, ultimately, product quality. The behaviour of the individuals interacting with the animals is incredibly important to reduce the stress the animals are under. Increases in temperature, heart rate, and respiratory rate can all be seen during a stressful situation (Knowles, 1995). In many studies, stress is often be measured by blood cortisol levels (Schwartzkopf-Genswein, K. S 2007), where an increase in blood cortisol levels can indicate a point of stress for the animal. However, in young calves the adrenal glands are not as reactive to adrenocorticotrophic hormone (ACTH) (Knowles, & Warriss, 2007) making it difficult to quantify stress levels.

Duration of transport is another variable that has been stated as a contributing factor to the amount of stress calves experience while on their journey. Calves reach a maximum cortisol
level between 30 and 60 minutes of transport, with no further increases throughout the rest of the duration (Sartorelli et al., 1992). Again, controversially some studies have reported that young calves do not respond to the stress of transport the same as older animals due to low adrenocorticotropic hormone activity, indicating that more research is required on the stress of transportation on young calves (Fell and Shutt, 1986; Hartmann et al., 1973; Mormede et al., 1982).

The age at which calves are transported has been stated to be a contributing factor to the stress the animal endures throughout the loading and unloading portion of the journey (Kent & Ewbank, 1986a). Younger calves have greater lying times during transit compared to older calves, suggesting that young calves are physically less equipped to handle transportation. Calves with more condition and muscle mass prior to the transport have been noted to tolerate the stress as the increased muscle mass allows for better balance (Schwartzkopf-Genswein, K. S 2007). Body condition score and haul duration have significant effects on feeding behaviour of calves up to 30 days after the transport date (Schwartzkopf-Genswein, K. S 2007). However, age of calves is challenging to determine, making it difficult to prove that age of calves is a significant factor contributing to transport stress. Calves under one month of age do not show the same increased heart rate, plasma cortisol, or plasma glucose, that is usually seen in older cattle and other species of livestock (Knowles et al., 1997).

**Stocking Density**

When in transit from the dairy farm of origin to the veal rearing facility, it is common to have a large number of calves on the trailer at one time. Out of various cattle types (feeder cattle, fat cattle and calves), male calves were more likely to become non-ambulatory or dead on a long haul (González et al., 2012b). Calves that endure a longer transportation time have increased probability of lameness and mortality (González et al., 2012b), suggesting that shorter hauls with lower stocking density is desired.

When stocking densities increase, there are an increased number of bruises and carcass damage as the animals are not able to orientate themselves (Knowles, 1995). Appropriate space allowance help avoid falls, struggles, and displacement within the trailer. A small space allowance has shown to increase mortality, the same can be true for excess space allowance as animals can become displaced more easily during abrupt changes of direction or speed of the
Thus, there exists some difficulty in establishing the proper stocking density to ensure there is enough calves they don't fall and lose balance but also not be over crowded.

**Climate**

Climate during transport may vary depending on the season and geographical location. Thermal stress on calves allows for compromise immune response, growth rate, and overall well-being (Stull and Reynolds, 2008). Varying climates impacts calves more so than mature animals, opening up a window for a variety of pathogens (Stull and Reynolds, 2008).

Calves that have experienced dystocia are particularly prone to thermal stress (Roland et al., 2016). Since male calves typically have a larger birth weight than females, they are more likely to experience a difficult calving, predisposing them to thermal stress. The thermoneutral zone is between 10 and 26°C for a newborn calf and between 0 and 23°C for a 1-month old calf (Wathes et al., 1983). Calves transported in the winter and summer months within North America are often in conditions outside of this thermoneutral zone. Bovine respiratory disease (BRD) is a leading cause of mortality in calves, male calves have shown to have an increased risk for BRD when compared to females (Cernicchiaro et al., 2012). Cases of BRD increase with increased change in temperature and increased wind chill (Cernicchiaro et al., 2012). When temperatures reached > 20°C, calves had higher rates of lameness and non-ambulatory calves occurring during the summer months (González et al., 2012b). Mortality is also increased when transportation temperatures are below freezing (Cernicchiaro et al., 2012). Knowles et al., (1997) found that calves younger than one month of age are unable to regulate their body temperature compared to older calves, when they were transported during the winter months.

**Nutrition**

Nutrition is a critical factor influencing structural growth, weight gain and the health of calves. At birth the calf is functionally a nonruminant. The digestive system development occurs in three basic stages (Davis and Drackley, 1998). The preruminant phase is the first 2 to 3 weeks of age when the calf consumes negligible amounts of dry feed and relies almost entirely on milk or milk replacer (Drackley, 2008). The abomasum releases digestive enzymes to break down fats, carbohydrates and protein. The energy requirements are met from the absorption of glucose
from the abomasum. When a calf drinks milk, it passes over the rumen to the abomasum via the esophageal groove. The abomasum makes up 60% of a newborn calf’s stomach capacity (Penn State, Feeding the Newborn Dairy Calf). By the time the calf is three to four months old, the abomasum makes up 20% of the capacity, and as the animal matures, that shrinks to only 8% of the stomach capacity (Penn State, Feeding the Newborn Dairy Calf). Prior to weaning the rumen must develop to be able to absorb and metabolize volatile fatty acids (Penn State, Feeding the Newborn Dairy Calf). It is the grain that develops the rumen and allows the calf to transition from a milk–based to a corn–based diet. In a newborn calf, the rumen makes up 25% of the calf’s stomach capacity. The rumen is constantly growing and changing, as the calf becomes a ruminant, and by three to four months of age, the rumen makes up 65% of capacity. With the digestive system of calves being very complex it is incredibly important to ensure that nutritional requirements are met to ensure optimal growth and maturation.

Calves with higher body condition prior to the transport have been noted to tolerate the stress, indicating that older calves are able to tolerate transit better than younger calves (Schwartzkopf-Genswein, 2007). Young calves should have limited transport times in order to flourish when arriving at the veal facility (Pempek et al., 2017).

Within Ontario, grain-fed veal has been shown to outgain milk-fed veal (Sargeant et al., 1994). Traditionally, restrictive milk diets were provided to calves where they were fed 8-10% of body weight in milk with starter offered for ad libitum consumption (Drackley, 2008). This amount of liquid feed is much lower than ad libitum intakes, which are in the range of 16% to 20% of BW (Hafez and Lineweaver, 1968). The restricted feeding approach allows only for maintenance needs and about 200 to 300 g/d of growth under thermoneutral conditions, impacting the ability of the calf to grow (Drackley, 2008). A greater volume of milk directed toward increased growth, performance and welfare of calves is beginning to become more common in the dairy industry (Todd et al., 2017). Benefits of greater milk volume in the first 2 to 3 weeks may be improved ability to withstand infectious challenges (Drackley, 2005). Calves fed a high volume of milk replacer had a faster recovery from diarrhea caused by C. parvum, had an increased ADG and higher feed efficiency than those fed a traditional restricted milk diet (Ollivett et al., 2012). Todd et al. (2017) also demonstrated the benefit of higher volumes of milk as calves on free access-feeding were treated less often for disease, had increased ADG, and improved structural growth when compared to calves fed restrictive volumes (3L twice daily) of
milk replacer. However, these improvements were not maintained throughout the post weaning process and no differences in carcass characteristics were seen (Todd et al., 2017). More research is required to truly discover the impact of nutrition of neonatal calves on dairy farms prior to transport.

**Prevalence and Impact of Disease**

Respiratory disease and diarrhea are the two most common causes of diseases in neonatal calves (Autio et al., 2007; Sivula et al., 2006; Windeyer et al., 2013). Both have been known to negatively impact average daily gain (ADG) in neonatal calves (Virtala et al., 1996) and have profound long-term impacts on productivity. Due to the impact that diarrhea and pneumonia have on health and growth there are significant costs, with treatment costing anywhere from $9.00 to $14.71 per calf (Berge et al., 2009; McGuirk, 2008; McGuirk and Peek, 2014; Windeyer et al., 2013). Depending on the size of the operation costs for disease treatment can be substantial, making disease prevention crucial to enhance economic viability. The negative impact that respiratory disease and diarrhea have on the calf rearing industry is significant and reduced incidence of these diseases can improve animal welfare, efficiency, and profitability of the calf rearing industries.

**Respiratory Disease**

Respiratory disease is one of the most severe and costly diseases in neonatal calves (Autio et al., 2007; Sivula et al., 2006) affecting 15% to 60% (Waltner-Toews et al., 1986; Windeyer et al., 2013; McGuirk, 2011; Pardon et al., 2015) of calves on dairy and veal farms. Bovine respiratory disease (BRD) can be defined as the clinical signs produced during an infection of the upper and/or lower respiratory tract (Delabouglique et al., 2017) including, nasal discharge, dry cough, body temperature of > 38.9°C, respiratory distress, and decreased appetite (McGuirk, 2011; McGuirk and Peek, 2014). Indicators of respiratory disease are often subtle and can be overlooked in many calf rearing facilities (Sivula et al., 2006), with calf caretakers diagnosing fewer cases of BRD when compared to veterinarians (Virtala et al., 1996). Svensson et al., (2003) found that respiratory disease detection by producers when a veterinarian was not present was half of the actual prevalence. This heavily implies that respiratory disease is difficult
to detect and that veterinarians can serve as educators to improve disease detection, ultimately improving calf welfare.

Respiratory disease in calves is often multifactorial (Ames, 1997). A variety of calf-level risk factors are involved with dairy calf pneumonia, including: dystocia, failure of passive transfer of immunity (Gordon & Plummer, 2007; Donovan et al., 1998), cleanliness of maternity pen and assisted first colostrum feeding (Svensson et al., 2003). Variables such as place of birth, housing, ventilation, and season have also been linked to severity and incidence rates of respiratory disease in calves (Gordon & Plummer, 2007; Svensson et al., 2003). With so many factors contributing to calf health, respiratory disease in particular, it is critical to optimize the housing and environment to ensure peak economic viability of the calf regardless of gender. Respiratory disease has several negative impacts on economic productivity. McCorkell et al., (2013) noted that some of the direct costs associated with bovine respiratory disease include reduced weight gain, human resources that are required to monitor the health of the calf, and most noticeably the financial costs associated with treatment. A diagnosis of pneumonia during the first 6 months of life results in slower growth rates and decreased productivity later in life (Bach et al., 2008; Donovan et al., 1998; Sivula et al., 1996). Respiratory disease has significant impacts on carcass weights of veal calves; Pardon et al., (2013) found that calves that experienced 1, 2, or >3 BRD episodes significantly decreased hot carcass weight on average of 8.2 kg, 22.4 kg and 41.6 kg, respectively. Carcass colour and fat cover are also impacted by respiratory disease (Pardon et al., 2013). Overall, there is an impact on carcass quality if the animal experiences a BRD event, not to mention the costs associated with lowered carcass quality.

Prevention of respiratory diseases in calves is critical to this industry to ensure optimal ADG, overall health, and improving the economic value of the animal. Intranasal vaccines have been a common source to limit and preventing the severity of pneumonia (Ollivett, 2014). Increased average daily gain within the first 8 weeks of life was associated with intranasal vaccination protocols (Ollivett, 2014). The eradication of BRD would be incredibly beneficial to the dairy and veal industries as it could increase the productivity of the calves up to 13% (Delabouglaise et al., 2017). Daily monitoring of calf rectal temperature has shown to help improve diagnosis of subclinical respiratory disease (McGuirk, 2011). Ensuring calves have proper ventilation has also proven effective in the prevention of respiratory disease (Lago et al.,
Enclosing the pen with solid fronts or covers should be avoided, a single solid barrier between calves is associated with decreased prevalence of respiratory disease (Lago et al., 2006). Proper nutrition is another vital component to aid with disease prevention in young calves. Todd et al., (2017) found that calves that were fed a restricted milk replacer diet tended to be treated for more preweaning diseases than calves fed free-access. There are many critical points in the growth and development cycle of calves to ensure optimal growth and productivity.

**Diarrhea**

Diarrhea is the most important disease in calves under 30 days of age (McGuirk, 2008; Virtala et al., 1996; Svensson et al., 2006) and is commonly overlooked by many producers. Incidence rates range from 15% to 29% (Pardon et al., 2015; Waltner-Toews et al., 1986; McGuirk, 2011) in veal and dairy calves. Over 20% of beef producers indicate that calf diarrhea has a significant impact (NAHMS, 1994), and over half of dairy calf mortality is accounted for by diarrhea (NAHMS 1998). Calf diarrhea is commonly caused by bacteria, viruses and parasites (Gomez et al., 2017; McGuirk, 2011). Currently, enterotoxigenic *Escherichia coli* (ETEC), *Cryptosporidium parvum*, rotavirus, and coronavirus appear to be the most significant infectious causes of calf diarrhea (Foster and Smith, 2009). The pathophysiology of diarrhea includes increased intestinal secretion and decreased intestinal absorption of fluids along with increased passage of intestinal contents, leading to calf dehydration (Berchtold, 2009). Diarrhea can be accompanied by intestinal cramping and abdominal pain.

Most enteric pathogen transmission occurs between the dam and calf, however, fecal-oral spread by colostrum or through environment contamination can also occur (McGuirk, 2008). *Cryptosporidium*, rotavirus, coronavirus and *Salmonella* spp are commonly isolated in 5 to 14 day old calves (McGuirk, 2008); however, diarrheic calves over 14 days of age are frequently tested for *E coli*, *Salmonella* spp, *Eimeria* spp, and *Giardia* spp (McGurirk, 2008). Diarrhea may also be caused by non-infectious causes such as; insufficient uptake of colostrum, poor sanitation, stress, and temperatures outside the thermoneutral zone (Cho et al., 2010). Proving that calf management is critical in prevention and elimination of calf diarrhea.

There are major economic costs associated with neonatal calf diarrhea, making it critical to control in calf herds. Donovan et al., (1998) found that 4 days of treatment gave an added an
extra 13 days onto the growing period of calves. This time period can seem small, however in a 77-day period this would reflect an additional 17% of time on-feed. Windeyer et al., (2014) found that growth of calves was influenced by whether they were treated for neonatal calf diarrhea. Diarrhea severely increases the mortality risk and decreased carcass quality (Pardon et al., 2013).

Factors involved in the occurrence of calf diarrhea can be grouped into ones associated with peripartum calving management, calf immunity, and environmental contamination (Cho and Yoon, 2014). Resistance to enteric pathogens is closely related to the judicious consumption of high-quality colostrum in sufficient quantities (Barrington and Parish, 2001). The neonatal dairy calf should ideally receive 3-4 L of colostrum within the first 6 hours after birth (Cortese, 2009). The health and nutritional status of the cow prior to parturition plays a key role in calving management as the quality of the colostrum can be impacted (Quigley and Drewy, 1998). Environmental impacts can include temperatures outside of the thermoneutral zone for calves, or contaminated pens. Neonatal calves are not able to effectively regulate body temperature when exposed to extreme weather conditions. In instances where extreme weather is present this may induce hypothermia or hyperthermia resulting in immune system impairment (Mee, 2004). Contaminated calving areas are one of the most common sources of calf diarrhea, followed by, presence of other infected animals, and overcrowding. There are many management techniques that are able to be adopted into the veal industry that would aid in the prevention and severity reduction of calf diarrhea.

Overall, a reduction of both respiratory disease and diarrhea in neonatal calves is vital for the dairy and veal calf industries as these diseases have substantial impacts on productivity and calf welfare. With improved calf health, calves can be more efficient, bringing higher profits. Healthier calves will have decrease number of growing days and decreased costs regarding antibiotic treatment.

**Antimicrobial Use and Resistance**

*Antimicrobial Use*

Antimicrobials are commonly used in livestock production to maintain health, productivity, and prevent disease. Global consumption of antimicrobials in food animal production was estimated at 63,151 (±1,560) tons in 2010 and is projected to rise by 67%, to
105,596 (±3,605) tons, by 2030 (Van Boeckel et al., 2015). This regular use of antimicrobials in modern agriculture could potentially increase selection pressure on bacteria to become resistant. In fact, the development of antimicrobial resistance in human and animal pathogens (Catry et al., 2016) has been associated with the high level of antimicrobial use in the veal calf sector (Bos et al., 2013). Most antimicrobial agents used for the treatment of bacterial infections may be categorized according to their principal mechanism of action. There are 4 major modes of action they include; interference with cell wall synthesis, inhibition of protein synthesis, interference with nucleic acid synthesis, and inhibition of a metabolic pathway (Tenover, 2006).

Common health abnormalities that are seen in calves arriving at veal facilities include dehydration, diarrhea, and inflamed navels (Pempeck et al., 2017). Due to this, many veal rearing facilities provide antimicrobials in the milk replacer to all calves for a few weeks after arrival (Pardon et al., 2012). However, there is little evidence to support this practice. Berge et al. (2005) saw a benefit using in-feed antimicrobial treatment beginning when the calves arrive at the facility. Calves with signs of respiratory disease or diarrhea at arrival to veal facilities have been known to receive more treatment during the growing stage (Wilson et al., 2000). Once at the rearing facility, the most frequent reason for prophylactic use included respiratory disease followed by arrival prophylaxis, diarrhea and non-specific bacterial enteritis (Pardon et al., 2012). Prophylactic treatment has proven to be beneficial in some studies (Rérat et al., 2012). Preventative group treatment yielded increased average daily gain and prevalence of respiratory disease is lower for calves that were prophylactically treated (Rérat et al., 2012). However, this study does not accurately reflect a veal rearing facility found in North America, as the calves within Rérat et al. (2012) were much older than the calves that would be entering the North American veal industry.

Antimicrobials have traditionally been used in three main ways — as growth promoters, as prophylactic or metaphylactic treatment for disease prevention and for therapeutic purposes (Barton, 2014). Growth promoters are given at relatively low concentrations and are much lower than therapeutic levels to enhance the feed-to-weight ratio for meat production (McEwen and Fedorka-Cray, 2002). For many years the use of antimicrobials as growth promoters was advocated for and the potential consequences of this practice went undetected. However, since the advocacy of using antimicrobials as a growth promotor, quantitative and qualitative relationships between the practice of in-feed antimicrobials for animals and the prevalence of
drug-resistant bacterial infections in humans has strengthened (Hershberger et al., 2005). It is incredibly important to note that as of December 1, 2018 growth promotion claims will be removed from the labels of all medically important antimicrobials in Canada, making use of antimicrobials for growth promotion prohibited.

Metaphylaxis, defined as timely mass medication of a group of animals to eliminate or minimize an expected outbreak of disease, and prophylaxis, defined as a measure taken to maintain health and prevent the spread of disease, are common management techniques used among livestock producers across the globe. Younger animals are known to have an increased prevalence of antibiotic resistant pathogens that are isolated from them likely due to the group provision of antibiotics (Khachatryan, 2003). Often, veal producers will prophylactically treat calves with antibiotics immediately upon entry (Rérat et al. 2012) as highlighted by a study in Belgium where all calves received group oral antibiotics in the first week of production (Pardon et al., 2012). Antimicrobials such as; tetracyclines, penicillins, or sulfonamides may be administered orally to aid with morbidity. They can also be injected such as ceftiofur, to treat or prevent diarrhea and pneumonia, both of which are important diseases of dairy calves (Friendship, 2000). Jiang et al., (2006) evaluated the impact of injection of ceftiofur treatment in calves on fecal shedding of ceftriaxone-resistant bacteria and found a significant increase in the fecal excretion of ceftriaxone-resistant bacteria, including Salmonella species. Ceftiofur is said to be the most appropriate antimicrobial to combat calf diarrhea as it is a broad spectrum β-lactam antimicrobial (Constable, 2004). Administration of ceftiofur to treat bacteremia and diarrhea in calves constitutes extra-label drug use, and ceftiofur should not be administered to calves to be processed as veal (Constable, 2004). Numerous infectious agents have been implicated in calf diarrhea. Ten different enteric pathogens are recognized as either major (BRV, BCoV, BVDV, Salmonella spp, E. coli, C. perfringens, and C. parvum) or emerging (bovine caliciviruses and BToV) pathogens (Cho and Yoon, 2014). Diarrhea can be fatal to neonatal calves due to dehydration and acidosis that may result in anorexia and ataxia, making it crucial to identify and prevent (Cho and Yoon, 2014).

Development of Antimicrobial Resistance

Acquired resistance to antimicrobials is one of the greatest concerns facing animal and human health worldwide (Tenover, 2006). It’s estimated that over 2 million human illnesses are
caused by AMR infections in the USA each year (CDC, 2013), and causing 700,000 deaths globally (O’Neill, 2016). The prevalence of antimicrobial resistant infections is increasing, as is the difficulty to treat the infections (O’Neill, 2016). It is assumed that AMR is intensified by the widespread use of antimicrobials in both human and veterinary medicine and by the agriculture industry (Public Health Agency of Canada, 2017). The concern of AMR infections has grown exponentially in the last few decades as antimicrobial usage documentation and the ever-advancing medical world. In 2016, approximately 1.0 million kilograms of medically important antimicrobials were distributed for sale for use in animals by the Canadian Animal Health Institute (CAHI) member companies (Health Canada, 2009). Of the antimicrobials distributed 99% were intended for use in food-producing animals and 1% was intended for use in companion animals (based on kilograms of active ingredient) (Health Canada, 2009). Bacterial resistance often results in treatment failure, which can have serious consequences, especially in critically ill patients. Microorganisms have the ability to travel into the environment through humans or livestock (Woohouse et al., 2014). Antimicrobial resistance has emerged in zoonotic enteropathogens (e.g., Salmonella spp., Campylobacter spp.), commensal bacteria (e.g., Escherichia coli, enterococci), and bacterial pathogens of animals (e.g., Pasteurella, Actinobacillus spp.), but the prevalence of resistance varies (McEwen and Fedorka-Cray, 2002). Correct use and dosage of antimicrobial drugs is critical to aid the battle of AMR evolving even further within the livestock industry.

Antimicrobial resistance occurs when microorganisms, that were at one time susceptible to medical treatment, mutate, select, or acquire genetic information encoding resistance (Tenover, 2006). Mutations have the ability to cause resistance by modifying or eliminating the binding site for the target protein, upregulating production of enzymes that inactivate the antimicrobial agent, downregulating or altering an outer membrane protein channel that the drug requires for cell entry, or lastly upregulating pumps that eject the drug from the cell (McManus, 1997). If a microbe gains new genetic information, three things can occur; conjugation, transduction, and transformation (McManus, 1997). Conjugation allows for the exchange of DNA to occur while clumping of the microbes. During transduction, resistant genes are transferred from 1 bacterium to another via bacterial viruses. Finally, transformations occur when bacteria acquire and incorporate DNA segments from other bacteria that have released their DNA complement into the environment after cell lysis, can move resistance genes into
previously susceptible strains (Tenover, 2006). These resistant microbes are then able to proliferate when under use of that drug, ultimately mitigating the effects of treatment (Tenover, 2006). When resistance through genetic exchange occurs, the microbe can become multidrug resistant, which is defined as resistance to $\geq 3$ antibacterial drug classes (Tenover, 2006).

Antimicrobial drugs are used in human medicine by prescription and over-the-counter medications as well as in veterinary medicine in companion animals and agricultural uses (Shea, 2003). With the growing use (and misuse) of antimicrobials, the agricultural industry has become a target for many involved in health care. The concern is that many of the antimicrobials used in food animals are identical to, or closely resemble drugs that are used in human medicine (McEwen and Fedorka-Cray, 2002). The agricultural use of antimicrobial agents that are used in humans or have a human analog increases the likelihood that human bacterial pathogens that have food animal reservoirs (ie, Campylobacter, Salmonella) will develop resistance or cross-resistance to drugs approved for use in human medicine (Shea, 2003). The Center for Disease Control and Prevention (CDC) recently estimated that 1.4 million Salmonella and 2.4 million Campylobacter infections occur each year in the United States. Young children have an increased risk of developing infections with AMR organisms linked directly to the agricultural use of antimicrobials (Shea, 2003). Antimicrobial resistance is a major concern and is most commonly found within food production animals; specifically, pork, poultry, and veal (Catry et al., 2007; Hendriksen et al., 2008; Persoons et al., 2010). The transfer of resistant bacteria from food-producing animals to humans is most evident in human bacterial pathogens that have food animal sources, such as Campylobacter, which has reservoirs in chickens and turkeys (Altekruse et al., 1999), and Salmonella, which has reservoirs in cattle, chickens, pigs, and turkeys (Angulo et al., 2000). Often herds of swine and flocks of poultry use all-in all-out methods where no animals are in contact with the successive population. However, previous studies have shown that certain pathogens have proven to persist in successive populations (Persoons et al., 2010).

There are often withdrawal periods recommended with most antimicrobials that are used within the livestock industry. Withdrawal times for antimicrobials are intended to prevent harmful drug residues in meat, milk, and eggs (McEwen and Fedorka-Cray, 2002). These waiting periods are indicated on drug labels and must be observed between treatment and consumption (McEwen and Fedorka-Cray, 2002). Many concerns in human and animal health have been expressed over the years in regard to the use, and overuse of antibiotics in agricultural
production as well as the presence of residues in the food chain (Mitchell et al., 1997). Antimicrobials are administered to animals by injections (e.g., intramuscular, intravenous, subcutaneous), orally in the food and water, topically on the skin and by intramammary and intrauterine infusions (Mitchell et al., 1997). Theoretically, all of these routes may lead to residues appearing in foods of animal origin such as milk, meat and eggs. Products are often tested for antimicrobial residues and if a certain level is exceeded the product will not enter the human food chain (McEwen and Fedorka-Cray, 2002). The slaughter classes most often associated with residues were culled dairy cows, veal calves and market hogs (Mitchell et al., 1997). It is imperative that the food industry continue inspecting milk, meat, and eggs to ensure that antimicrobial residues do not enter the human food chain contributing to the global AMR concern. It is also important to monitor and ensure that producers are following appropriate withdrawal period before submitting meat, milk, or eggs into the human food chain.

Factors that have the potential to influence AMR may include species of animal, dose, duration of treatment, numbers of animals treated, animal husbandry practices, animal movement, and potential for environmental spread (McEwen and Fedorka-Cray, 2002). There is still much to be done in the way of determining the impact that antimicrobial use in the livestock sector plays with AMR. Judicious use of antimicrobial drugs— using the appropriate drug at the appropriate dosage and for the appropriate duration—is one of the most important means of reducing the selective pressure that helps resistant organisms emerge (Tenover, 2006). Steps have been taken in Europe with the attempt to slow and revers the AMR, the livestock industry has not seen a dramatic profit loss indicating that reduction of antimicrobial use is a viable solution to slow the spread of AMR (DANMAP, 1999). Antimicrobial stewardship has become more important than ever with the rise of AMR. To promote antimicrobial awareness Page et al., (2014) developed the 5Rs approach to antimicrobial stewardship. The 5Rs include; responsibility of everyone using antimicrobials to use them as directed, reduction of the use of antimicrobials, refinement to maximize the odds of treatment success, replacement of antimicrobials wherever possible, and finally review of regulatory initiatives ensuring the alignment with current scientific evidence. Medical professionals must work with all stakeholders to find strategies to slow the resistance course. By following the 5Rs of antimicrobial stewardship it is possible to slow and potentially reverse the effects of AMR in the medical world.
Rationale for thesis

The focus of this thesis is on male dairy calf health. There has been very little literature published in North America on this topic in the previous two decades. With animal welfare, antimicrobial resistance, and antimicrobial use becoming increasingly important, a better understanding of factors impacting male dairy calf health is needed to address these challenges.

Thesis objectives

The specific objectives of each chapter were:
1) Describe health status of calves on arrival at the veal rearing facility
2) Determine which are associated with morbidity and mortality
3) Assess the impact of health status on arrival on average daily gain of the calves

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CHAPTER 2: RISK FACTORS IDENTIFIED AT ARRIVAL ASSOCIATED WITH MORBIDITY AND MORTALITY AT A GRAIN-FED VEAL FACILITY: A PROSPECTIVE SINGLE COHORT STUDY

K.J Scott, D.F. Kelton, T.F Duffield, and D.L. Renaud
RISK FACTORS IDENTIFIED AT ARRIVAL ASSOCIATED WITH MORBIDITY AND MORTALITY AT A GRAIN-FED VEAL FACILITY: A PROSPECTIVE SINGLE COHORT STUDY

ABSTRACT

Aside from feed costs, morbidity and mortality represent some of the highest costs for producers within the veal industry. Determining factors associated with morbidity and mortality on farm aids the profitability of the veal industry. The objectives of this study are to describe the health status of calves at arrival to a grain fed veal facility, and determine characteristics of the arriving calf with morbidity and mortality. From January to December 2017 a total of 998 calves were sampled upon arrival at a veal rearing facility. At arrival, the calves were assessed for health abnormalities, weighed, vaccinated, and had blood collected to determine serum total protein. The calves were weighed throughout the 11-week growing phase on days 0, 49 and 79, and treatments were recorded. Body mass index was calculated from the length, height, and weight of the calves was divided into quartiles and fecal and navel scores were collapsed into 3 categories. Two mixed effect logistic regression models were developed for morbidity, a model for morbidity occurring within the first 21 days of arrival at the facility, and a model for overall morbidity. In the first 21 days following arrival, 676 calves (68.3%) were treated at least once. The only explanatory variable that remained in the < 21 day morbidity model was BMI. Calves that arrived at the facility with a BMI of ≥ 371 g/cm were less likely to be treated than calves that entered with a lower BMI. For the >21 day morbidity model none of the variables were significant upon backward selection of the final model. A mixed effect logistic regression model was also created for calf mortality. A total of 75 calves (7.5%) died over the within the 11-week period of observation at this facility. Calves that arrived at the facility with a fecal score of 2 were more likely to die. Calves that had a body mass index of > 371 g/cm² were less likely to die than calves that had a body mass index < 330 g/cm². These results show the importance of assessing calves upon arrival to a veal facility as a measure of identifying calves at high-risk for both morbidity and mortality. This information could improve the viability of the veal industry and increase the profitability. However, further research is required to help determine effective preventative measures.
INTRODUCTION

Mortality and morbidity are significant challenges faced by veal producers. The risk of mortality varies; however, recent studies have found that 4% to 8% of calves die during the veal production period (Bahler et al., 2012; Pardon et al., 2012a; Renaud et al., 2018). Disease also occurs commonly, with Pardon et al. (2012a) reporting that 25% of calves develop one or more diseases between arrival and slaughter. The high levels of disease has led to large quantities of antimicrobials being used in the veal calf sector (Bos et al., 2013) which has contributed to the development of antimicrobial resistance in commensal and animal pathogens (Catry et al., 2016; Di Labio et al., 2007). With these levels of morbidity, mortality, and antimicrobial use, it is important for the veal industry to address these challenges and determine factors that could be used to improve animal health and welfare.

A recent study demonstrated that calves at high risk for mortality could be identified on arrival to a milk-fed veal facility (Renaud et al., 2018). If the identification of calves at high-risk for mortality can be accomplished, it may provide an opportunity to selectively treat with antibiotics or supportive therapy and reduce overall antibiotic use (Pardon et al., 2015). However, to date there has not been a large-scale epidemiological study that evaluated the impact of health status at arrival on morbidity occurring through the growing period, which could provide further evidence that selective therapy may be an area to explore. There also is a paucity of literature that has evaluated the incidence of morbidity on Canadian veal farms as the last study evaluating these levels was conducted nearly 2 decades ago (Sargeant et al., 1994).

Thus, the objectives of this study were to describe the health status of calves on arrival at a grain-fed veal facility and to associate characteristics of the arriving calf with morbidity and mortality.

MATERIALS AND METHODS

Experimental Design

A prospective cohort study was conducted from January to December 2017 to collect data on arrival from calves entering a veal rearing facility in southwestern Ontario, Canada. This study was conducted in accordance with University of Guelph Animal Care Committee requirements (Animal Use Protocol: #3695). The veal facility was selected based on proximity to the University of Guelph and willingness to participate in the study. The facility is a grain-fed
veal rearing operation, where calves are fed milk replacer twice daily for 49 days and transitioned to a grain-based diet following weaning. Calves were housed in individual stalls, with slatted rubber flooring for the first 21 days after arrival and after 21 days, the individual partitions were removed, and calves were housed in groups of 5. Groups of calves arrived at the facility every 3 weeks to fill a room of 80 calves. After 11 weeks, the calves were transported to a larger group housing facility and were slaughtered after an additional 20 weeks. Data were not captured beyond 11 weeks as the finishing facility did not have well-kept records.

Calves were transported from their dairy farm of origin or a local auction mart to the rearing facility. Upon arrival at the veal rearing facility, the facility staff weighed the calves and an intranasal bacterin (Once PMH® IN) and an intranasal viral vaccine (Bovillis® IN) were administered. A single graduate student, trained by a veterinarian, evaluated all the calves on arrival using a standardized health scoring system. Treatment and mortality records were obtained from the producer and were used for the analysis. Heifer and beef cross calves were excluded from the dataset due to the low numbers.

**Standardized Health Scoring System**

An iPad (Apple Inc., Cupertino, CA) with the Calf Health Scorer app (University of Wisconsin-Madison, Madison, WI) and Qualtrics™ (http://www.qualtrics.com/) was used to facilitate the health scoring. The Calf Health Scorer app provided images and descriptions to evaluate the respiratory system (nose, eye, ear, cough; McGuirk and Peek, 2014), attitude, fecal consistency (McGuirk, 2008), navel inflammation (adapted from Fecteau et al., 1997), joint swelling, and rectal temperature. Fecal score was categorized into 3 levels; normal-semi formed, loose but stays on top of bedding, watery and sifts through bedding. Navel score was also categorized into 3 levels; normal—slightly warm but not warm or painful, swelling with pain or heat, slight lameness, and swelling with severe pain, heat and lameness. These variables were categorized to aid with elimination of misclassification between normal and slightly abnormal characteristics. A Qualtrics form was used to collect data on the degree of clinical dehydration (Wilson et al., 2000), body condition scoring (BCS) (Wilson et al., 2000), and the presence of a sunken flank (Bähler et al., 2012). Additional information collected using the Qualtrics survey included: hip height (cm), length (cm) of the calf’s withers to lumbosacral junction, and navel diameter (mm) defined as the circumference at the base of the calf’s umbilicus. Body mass index (BMI) was calculated using weight on arrival (g) divided by the sum of the calf’s length from
withers to lumbosacral junction and hip height (Mei et al., 2002). This allowed for a more objective score when compared to subjective body condition scoring. Temperature humidity index (THI) was calculated for each day calves arrived at the facility using a local weather station (Historical Weather Data, http://climate.weather.gc.ca/), creating a daily temperature and humidity average within an equation as seen in Dikmen and Hansen (2009).

**Blood Collection**

Blood was collected from the jugular vein into a 10 ml sterile blood collection tube without an anticoagulant (BD Vacutainer; Becton, Dickson and Co., Franklin Lakes, NJ, USA). Blood samples were allowed to clot and then centrifuged at 1,500 × g for 15 minutes at approximately 20°C. Serum was separated and serum total protein (STP) was evaluated using a digital refractometer (Misco® Palm Abbe™ #PA202x).

**Sample Size Calculation**

A proportion estimation sample size calculation was used to determine the required number of calves. Based on previous work by Pardon et al. (2015) and Renaud et al. (2018), it was estimated that calves identified on arrival with a health abnormality would have a morbidity risk of 26% whereas those without an abnormality would have a morbidity risk of 17%. Using 95% confidence interval and 80% power, a sample size of 916 calves was required.

**Statistical Analysis**

All statistical analyses were conducted using Stata 14 (StataCorp LP, College Station, TX). Data were imported from Microsoft Excel (Microsoft®; Redmond, WA) into Stata 14 and checked for completeness. Causal diagrams (Figure 2.1 and Figure 2.2) were created to illustrate the hypothesized relationship between the dependent and independent variables and was used to guide the analyses. Descriptive statistics were generated for all explanatory variables in the dataset.

Mixed logistic regression models were built for morbidity and mortality variables, controlling for the room of the calves as a random effect. Morbidity can be defined as a calf being treated for signs of respiratory disease or diarrhea after arrival at the veal rearing facility. There were two morbidity models created; a model for calves that were treated ≤ 21 days following arrival at the facility, and calves that were treated at all within the 11 weeks at the facility. When observing the overall morbidity within the subset it appeared that there were two
peaks of morbidity. The first peak occurred within the first 21 days of the calves being at the facility, and the second was later on in the growing period. To properly analyze and describe the data it was decided to create two separate models to analyze morbidity within the first 21 days after arrival and morbidity greater than 21 days after arrival. Many studies (Bahler et al., 2012; Pardon et al., 2012a; Winder et al, 2016) have identified that the first 21 days following arrival are the period of greatest risk for disease; thus, this model was built to explore this critical phase. A lowess smoothing curve was generated to assess the linearity of each predictor variable to the outcome on a log odds scale. If a variable failed to meet the linearity assumption, the variable was categorized into quartiles. In the mortality model, STP was categorized; whereas, BMI was categorized in the morbidity model. Spearman rank coefficients were used to determine collinearity between the variables. If the correlation coefficient between 2 variables was ≥ 0.8, only one variable was retained, based on the fewest number of missing values, reliability of the measurement, and biological plausibility. Explanatory variables that were unconditionally associated (P-value < 0.2) with the outcome in univariable mixed logistic regression models were offered to a multivariable model through a manual backward stepwise removal process. For all variables of interest, a P-value ≤ 0.05 was used to assess significance. Confounding was assessed before the removal of any predictors. If the difference in the log odds of a significant variable between the reduced and full model was > 20% and was not an intervening variable identified in the causal diagram, the variable was considered a confounder and was kept in the model regardless of statistical significance. However, if the difference in the log odds of a significant variable between the reduced and full model was < 20%, it was removed. Two-way interactions were evaluated based on evidence from the literature and were kept in the models if significant (P-value ≤ 0.05). Lastly, prior to removal, a likelihood ratio test was conducted to test the overall significance of the predictor variable, and if not significant (P-value ≤ 0.05), the variable was removed from the model. The fit of the models was assessed using Pearson and deviance $\chi^2$ tests. These tests were used in the logistic model as solely binomial data (i.e. leading to the number of covariate patterns to be much lower than the number of data points in the dataset) was included in the model (Dohoo et al., 2010b). Outliers and their impact on the model were assessed graphically using Pearson residuals. If any covariate patterns were determined to be outliers or greatly impacted the model, they were investigated further for the purposes of appropriate interpretation, although ultimately, they were kept in the model.
RESULTS

Descriptive Statistics

Out of 14 groups of calves, a total of 998 calves of unknown age were assessed from January to December 2017. It was suspected that the majority of the calves would be between 3 to 7 days of age (Renaud et al., 2018). All variables were examined for any irregularities based on their descriptive statistics, including mean, median, and minimum and maximum values. There were 15 explanatory variables in the data set for this study. Descriptive statistics of these variables can be found in Table 2.1 and 2.2.

Morbidity

In the first 21 days following arrival, 676 calves (68.3%) were treated at least once, with 420 calves (42.0%) and 501 calves (50.2%) being treated for diarrhea and pneumonia, respectively. Morbidity occurring within the first 21 days of calves arriving to the facility was used as the dependent variable. The variables that had a $P$-value of $< 0.2$ in univariable analysis included navel diameter, group treatment, and BMI. The only predictor variable that remained in the final model was BMI (Table 2.3). No interaction terms were found to be significant. The Pearson residuals were examined in a scatter plot and no outliers were observed. The bayesian information criterion confirmed this measurement to be a better fit for the data. Calves that arrived at the facility with a BMI of $\geq 371$ g/cm were less likely to be treated than calves that entered with a lower BMI ($P < 0.01$ (95% CI: 0.347 - 0.756))

A total of 877 (88.6%) of calves were treated at least once over the 11-week housing period at the grain-fed veal facility. Four hundred and twenty-nine calves (43.3%) were treated for diarrhea, whereas, 825 calves (83.3%) were treated for respiratory disease over the 11-week period. Calf rectal temperature was categorized into quartiles due to lack of linearity. Three hundred-fourty eight (35%) calves were exposed to group treatment. Univariable analysis, as seen in Table 2.4, revealed navel scores, rectal temperature, STP, and group treatment were predictors. However, following manual backward step-wise elimination, none of these variables were significant in the final model.

Mortality

A total of 75 calves (7.55%) died over the within the 11-week period under observation at this facility. The main cause of mortality was respiratory disease and diarrhea. The average
growth day of mortality was 41 days after arrival. The earliest date of mortality was one day after arrival and the latest being 77 days after arrival. Group treatment, BMI, navel score, fecal score, and STP were associated with mortality in univariable analysis. After manual backward selection the final model included fecal score, and body mass index measured at arrival (Table 2.5). No interaction terms were found to be significant and 6 outliers were explored further. These calves were kept in the final model. Calves that arrived at the facility with a fecal score of 2 were more likely to die. Calves that had a body mass index of > 371 g/cm² were less likely to die than calves that had a body mass index of < 330 g/cm² (P = 0.01 (95% CI: 0.167 - 0.822).

**DISCUSSION**

This study identified parameters measured upon arrival at a veal facility that are associated with morbidity and mortality. The level of body mass index were associated with morbidity in the first 21 days of arrival as well as mortality, while fecal score was associated with mortality. These factors could be taken into consideration when processing new animals arriving at a veal rearing facility. For those producers that are able to; fecal scoring can be done on the farm of origin. Making contracts with surrounding dairies to provide healthy calves that are able to thrive once at the veal facility would prove to be beneficial for both the dairy farm of origin as well as the veal producer, as calves would bring a higher profit at the end of the production cycle.

A potential limitation to consider is that the producer was very selective of which calves they brought into to the facility. They would commonly leave calves that were visually less healthy on the farm of origin. This may have introduced some selection bias and could limit the external validity of the study as very few veal producers in Canada have such a high-level of control over the calves purchased. Another limitation was the inability to control for the source farm of the calves in the analysis. Previous studies have found that the source of the arriving calves are important factors to consider when purchasing calves (Renaud et al., 2018), however, as this farm did not record the source of origin it could not be included in the analysis.

Solely evaluating the weight of calves measured at arrival does not take into account variation in the body condition and height and length of calves. Therefore, a body mass index was developed as a composite measure made up of weight, height and length of the calf to allow for the entire calf to be evaluated rather than solely weight. Mei et al. (2002) used a similar scale
(kg/m²) to what was used in this study and found BMI scale was the most accurate at detecting the condition of young calves. In this study, BMI was associated with calf morbidity within the first 21 days after arrival to the rearing facility. This finding is comparable to other studies where a lower weight or height was associated with higher morbidity and mortality (Brscic et al., 2012; Virtula et al., 1996; Winder et al., 2016). Longer calves were also found to be at greater risk to be a stillborn when compared to shorter calves with the same body weight (Barrier et al., 2013) which suggests that longer calves could be predisposed to dystocia and therefore be at a health disadvantage at birth. This BMI could be a reflection of nutritional status of the calf prior to arrival, the size of the calf at birth, and the age of the arriving calf (Winder et al., 2016).

Previous disease will also reduce average daily gain (Windeyer et al., 2014; Virtala et al., 1996) and impact body weight (Stanton et al., 2010) but could reduce the animal’s BMI.

A high-level of morbidity was identified in this study, with 68.3% (n = 676) of calves being treated at least once within the first 21 days of arrival and 89% (n=877) being treated over the entire period under observation. Other studies have identified that 15 to 60% for respiratory disease and diarrhea (McGuirk, 2011; Pardon et al., 2015; Waltner-Toews et al., 1986; McGuirk, 2011; Windeyer et al., 2013), identify that number of calves treated in this study is high. In the past it has been noted that producer diagnosis is not always consistent and effective (Virtala et al., 1996) and as we relied on producer diagnosis and treatment of disease, this could have led to the high proportion of calves being treated for disease.

Neonatal calf diarrhea is one of the most important diseases in calves under 30 days of age (McGuirk, 2008; Pardon et al., 2012 Virtala et al., 1996). An interesting finding in this study was that calves with a fecal score of 3 was not associated with mortality, whereas, calves arriving with a fecal score of 2 had a greater risk of mortality in the production period. A hypothesis to describe this result would be that calves that have loose fecal scores but not solely liquid are already dehydrated and are unable to pass any more fluid to present with diarrhea. This is a particularly interesting finding and will merit further exploration.

Serum total protein concentration proved to be significant in univariable analysis of overall calf morbidity but was removed for the final model. It is interesting that this particular variable was not significant in the final model as many studies have found it to be associated with morbidity and mortality of young calves (Donovan et al., 1998: Renaud et al., 2018). There have been many discussions on the most accurate cut point of passive transfer. Previously, the
suggested cut points for failure of passive transfer (FPT) using a refractometer were < 5.2 g/dL STP in healthy calves (Tyler et al., 1996; Windeyer et al., 2014), and < 5.5 g/dL STP in clinically ill calves (Tyler et al., 1996; McGuirk and Collins, 2004). However, in contrast to previous studies, Chigerwe et al. (2015) stated that serum immunoglobulin G (IgG) and STP concentrations of 2001–2500 mg/dl and 5.8–6.3 g/dL respectively, were considered optimum for indicating adequate passive transfer of colostral immunity in pre-weaned dairy calves. In our study, univariable analysis showed STP > 5.7 g/dL was protective against morbidity suggesting that a higher cutpoint may be necessary when evaluating the impact of STP on disease. Mori et al., (2007) found that total protein decreased significantly at day 14 and remained stable until day 42 and then increased up to day 84. The discrepancies between these cut points and the historical cut points used is sufficiently disparate that further research may be necessary to determine what the cut points should be used when evaluating IgG and STP levels on arrival at veal facilities.

It’s important to note that the provision of oral antimicrobials for the first week following arrival was not associated with morbidity or mortality. Over the 14 lots, 348 (35%) calves were group treated. It is not uncommon to have producers treating prophylactically to prevent disease outbreaks and metaphylactically to control pathogens once they have invaded the facility. Oral group antimicrobial treatments, account for 12% and 88% of prophylactic and metaphylactic protocols, respectively (Pardon et al., 2012). Jarrige et al., (2017) stated that it would be helpful to the industry to explore the necessity and effectiveness of this strategy as it represents the majority of antimicrobial consumption (Lava et al., 2016; Jarrige et al., 2017; Pardon et al., 2012b). Prophylactic therapy at the time of movement and grouping is of the greatest benefit for calves that do not have a history of BRD before enrollment (Stanton et al., 2010), making health status at arrival incredibly important to determine if prophylactic antibiotic therapy is necessary. It is interesting to note that although there is little information supporting the use of prophylactic treatment; it is still a common management technique among producers.

**CONCLUSION**

Based on the results of this study, measuring the health status of calves upon arrival at a veal facility can aid in early detection of disease. Reduction of morbidity and mortality at veal production facilities may be possible through early interventions provided at arrival. As the prevalence of these health abnormalities is high at arrival, future studies should explore how to
prevent these conditions from occurring prior to arrival through improved management of transport and early life on the dairy farms of origin.

REFERENCES


https://doi.org/10.3168/jds.2011-4699


Table 2.1. Frequency and prevalence of categorical variables measured upon arrival at a grain-fed veal facility.

<table>
<thead>
<tr>
<th>Variable Name</th>
<th>Description</th>
<th>Frequency</th>
<th>Prevalence</th>
</tr>
</thead>
<tbody>
<tr>
<td>Attitude</td>
<td>Bright, alert, and responsive</td>
<td>918</td>
<td>92.0%</td>
</tr>
<tr>
<td></td>
<td>Dull &amp; Depressed</td>
<td>80</td>
<td>8.0%</td>
</tr>
<tr>
<td>Nasal Discharge</td>
<td>Normal, serous discharge</td>
<td>996</td>
<td>99.8%</td>
</tr>
<tr>
<td></td>
<td>Small amount of unilateral, cloudy</td>
<td>2</td>
<td>0.2%</td>
</tr>
<tr>
<td></td>
<td>discharge</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Ear Position</td>
<td>Normal</td>
<td>956</td>
<td>95.8%</td>
</tr>
<tr>
<td></td>
<td>Ear flicking</td>
<td>39</td>
<td>3.9%</td>
</tr>
<tr>
<td></td>
<td>Slight unilateral ear drop</td>
<td>3</td>
<td>0.3%</td>
</tr>
<tr>
<td>Ocular Discharge</td>
<td>Normal</td>
<td>940</td>
<td>94.2%</td>
</tr>
<tr>
<td></td>
<td>Mild ocular discharge</td>
<td>55</td>
<td>5.5%</td>
</tr>
<tr>
<td></td>
<td>Moderate bilateral ocular discharge</td>
<td>2</td>
<td>0.2%</td>
</tr>
<tr>
<td></td>
<td>Heavy ocular discharge</td>
<td>1</td>
<td>0.1%</td>
</tr>
<tr>
<td>Cough Score</td>
<td>No cough</td>
<td>906</td>
<td>90.8%</td>
</tr>
<tr>
<td></td>
<td>Induce single cough</td>
<td>92</td>
<td>9.2%</td>
</tr>
<tr>
<td>Fecal</td>
<td>Normal &amp; Semi-formed, pasty</td>
<td>863</td>
<td>86.5%</td>
</tr>
<tr>
<td></td>
<td>Loose, but stays on top of bedding</td>
<td>75</td>
<td>7.5%</td>
</tr>
<tr>
<td></td>
<td>Watery, sifts through bedding</td>
<td>60</td>
<td>6.0%</td>
</tr>
<tr>
<td>Navel</td>
<td>Normal &amp; Slightly enlarged, not warm or painful</td>
<td>799</td>
<td>80.1%</td>
</tr>
<tr>
<td></td>
<td>Slightly enlarged with slight pain or moisture</td>
<td>170</td>
<td>17.0%</td>
</tr>
<tr>
<td></td>
<td>Enlarged with pain, heat or malodorous discharge</td>
<td>29</td>
<td>2.9%</td>
</tr>
<tr>
<td>Dehydration</td>
<td>&lt; 5% dehydrated</td>
<td>623</td>
<td>87.9%</td>
</tr>
<tr>
<td></td>
<td>5 to 7% dehydrated</td>
<td>47</td>
<td>6.6%</td>
</tr>
<tr>
<td></td>
<td>&gt; 7% dehydrated</td>
<td>39</td>
<td>5.5%</td>
</tr>
<tr>
<td>Group treatment</td>
<td>No</td>
<td>645</td>
<td>64.9%</td>
</tr>
<tr>
<td>administered at arrival</td>
<td>Yes</td>
<td>348</td>
<td>35.1%</td>
</tr>
</tbody>
</table>
Table 2.2. Mean and standard deviation of continuous variables measured upon arrival at a grain-fed veal facility.

<table>
<thead>
<tr>
<th>Variable Name</th>
<th>Description</th>
<th>Mean</th>
<th>Standard Deviation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Length (cm)</td>
<td>Length from withers to lumbar sacral junction</td>
<td>46.83</td>
<td>2.86</td>
</tr>
<tr>
<td>Height (cm)</td>
<td>Calf hip height</td>
<td>86.69</td>
<td>3.36</td>
</tr>
<tr>
<td>Navel Diameter (mm)</td>
<td>Diameter of calf's navel</td>
<td>25.37</td>
<td>8.99</td>
</tr>
<tr>
<td>Weight on Arrival (kg)</td>
<td>Weight on arrival</td>
<td>46.96</td>
<td>4.84</td>
</tr>
<tr>
<td>Serum Total Protein</td>
<td>Serum Total Protein</td>
<td>5.76</td>
<td>0.66</td>
</tr>
<tr>
<td>Body Mass Index (g/cm)</td>
<td>BMI</td>
<td>351.56</td>
<td>32.07</td>
</tr>
</tbody>
</table>
Table 2.3. Results of final multivariable logistic regression models evaluating risk factors on arrival for morbidity within the first 21 days at the veal rearing facility. (N = 992)

<table>
<thead>
<tr>
<th>Variable (g/cm²)</th>
<th>Description</th>
<th>OR</th>
<th>P-Value</th>
<th>95% Confidence Interval</th>
<th>Prevalence</th>
</tr>
</thead>
<tbody>
<tr>
<td>BMI</td>
<td>&lt;330</td>
<td>Referent</td>
<td></td>
<td></td>
<td>24.80% (n = 246)</td>
</tr>
<tr>
<td></td>
<td>331-349</td>
<td>0.86</td>
<td>0.46</td>
<td>(0.57, 1.29)</td>
<td>24.90% (n = 247)</td>
</tr>
<tr>
<td></td>
<td>350-370</td>
<td>0.70</td>
<td>0.08</td>
<td>(0.47, 1.04)</td>
<td>24.90% (n = 247)</td>
</tr>
<tr>
<td></td>
<td>&gt;371</td>
<td>0.51</td>
<td>&lt;0.01</td>
<td>(0.35, 0.76)</td>
<td>25.40% (n = 252)</td>
</tr>
</tbody>
</table>
Table 2.4. Results of univariable analysis logistic regression models evaluating risk factors on arrival for morbidity days at the veal rearing facility. (N = 993)

<table>
<thead>
<tr>
<th>Variable</th>
<th>Description</th>
<th>OR</th>
<th>P-Value</th>
<th>95% Confidence Interval</th>
<th>Prevalence</th>
</tr>
</thead>
<tbody>
<tr>
<td>Navel Score</td>
<td>0 and 1</td>
<td>Referent</td>
<td></td>
<td></td>
<td>80.06% (n = 799)</td>
</tr>
<tr>
<td></td>
<td>2</td>
<td>1.50</td>
<td>0.20</td>
<td>(0.807, 2.798)</td>
<td>17.03% (n = 170)</td>
</tr>
<tr>
<td></td>
<td>3</td>
<td>1.19</td>
<td>0.78</td>
<td>(0.343, 4.142)</td>
<td>2.91% (n = 29)</td>
</tr>
<tr>
<td>Rectal Temperature (°C)</td>
<td>&lt;38.6</td>
<td>Referent</td>
<td></td>
<td></td>
<td>25.85% (n = 258)</td>
</tr>
<tr>
<td></td>
<td>38.6 - 38.7</td>
<td>0.85</td>
<td>0.60</td>
<td>(0.471, 1.542)</td>
<td>15.63% (n = 156)</td>
</tr>
<tr>
<td></td>
<td>38.8 - 39.1</td>
<td>0.96</td>
<td>0.90</td>
<td>(0.563, 1.654)</td>
<td>25.75% (n = 257)</td>
</tr>
<tr>
<td></td>
<td>&gt; 39.2</td>
<td>1.54</td>
<td>0.13</td>
<td>(0.88, 2.713)</td>
<td>32.77% (n = 327)</td>
</tr>
<tr>
<td>Serum Total Protein (g/dL)</td>
<td>&lt;5.3</td>
<td>Referent</td>
<td></td>
<td></td>
<td>22.09% (n = 209)</td>
</tr>
<tr>
<td></td>
<td>5.3 - 5.6</td>
<td>0.93</td>
<td>0.82</td>
<td>(0.508, 1.712)</td>
<td>31.18% (n = 295)</td>
</tr>
<tr>
<td></td>
<td>5.7 - 6.1</td>
<td>0.64</td>
<td>0.15</td>
<td>(0.352, 1.174)</td>
<td>25.37% (n = 240)</td>
</tr>
<tr>
<td></td>
<td>&gt; 6.2</td>
<td>0.65</td>
<td>0.18</td>
<td>(0.349, 1.215)</td>
<td>21.35% (n = 202)</td>
</tr>
<tr>
<td>Group Treatment</td>
<td>No</td>
<td>Referent</td>
<td></td>
<td></td>
<td>64.95% (n = 645)</td>
</tr>
<tr>
<td></td>
<td>Yes</td>
<td>0.61</td>
<td>0.19</td>
<td>(0.293, 1.269)</td>
<td>35.05% (n = 348)</td>
</tr>
</tbody>
</table>
Table 2.5. Results of final multivariable logistic regression models evaluating risk factors on arrival for mortality at the veal rearing facility. (N = 992)

<table>
<thead>
<tr>
<th>Variable</th>
<th>Description</th>
<th>OR</th>
<th>P-Value</th>
<th>95% Confidence Interval</th>
<th>Prevalence</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Fecal Score</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>0 and 1</td>
<td>Referent</td>
<td></td>
<td></td>
<td></td>
<td>86.47% (n = 863)</td>
</tr>
<tr>
<td>2</td>
<td>2.69</td>
<td>0.01</td>
<td></td>
<td>(1.263, 5.724)</td>
<td>7.52% (n = 75)</td>
</tr>
<tr>
<td>3</td>
<td>0.32</td>
<td>0.27</td>
<td></td>
<td>(0.042, 2.408)</td>
<td>6.01% (n = 60)</td>
</tr>
<tr>
<td><strong>Body Mass Index</strong></td>
<td>&lt;330 Referent</td>
<td></td>
<td></td>
<td></td>
<td>24.80% (n = 246)</td>
</tr>
<tr>
<td>(g/cm²)</td>
<td>331-349</td>
<td>1.01</td>
<td>0.98</td>
<td>(0.538, 1.896)</td>
<td>24.90% (n = 247)</td>
</tr>
<tr>
<td>350-370</td>
<td>0.56</td>
<td>0.11</td>
<td></td>
<td>(0.277, 1.14)</td>
<td>24.90% (n = 247)</td>
</tr>
<tr>
<td>&gt;371</td>
<td>0.37</td>
<td>0.01</td>
<td></td>
<td>(0.167, 0.822)</td>
<td>25.40% (n = 252)</td>
</tr>
</tbody>
</table>
Figure 2.1. Causal diagram describing the relationship of measured variables to the outcome morbidity.
Figure 2.2. Causal diagram describing the relationship of measured variables to the outcome mortality.
CHAPTER 3: FACTORS ASSOCIATED WITH AVERAGE DAILY GAIN AT A GRAIN-FED VEAL FACILITY: A PROSPECTIVE SINGLE COHORT STUDY.

K.J Scott, D.F. Kelton, T.F Duffield, and D.L. Renaud
FACTORS ASSOCIATED WITH AVERAGE DAILY GAIN AT A GRAIN-FED VEAL FACILITY: A PROSPECTIVE SINGLE COHORT STUDY

ABSTRACT

The objective of this cohort study was to associate factors identified upon arrival at a veal rearing facility in Southern Ontario with average daily gain. Calves were visually assessed and scored upon arrival, weighed, vaccinated and blood was drawn from the jugular vein to determine serum total protein. Weights were taken on day 0, 49 and 79 throughout the growing period in this facility, and treatments and mortality dates were recorded. Three mixed linear regression models were created to model average daily gain as an outcome variable. The first model evaluated average daily gain over the first 7 weeks at the veal rearing facility. Calves that entered the facility with a BMI $\geq 37.1$ g/cm$^2$ gained 73g more per day than calves that arrived with a BMI lower than 33.1 g/cm$^2$ ($P < 0.01$, 95% CI: 0.031 - 0.115kg/day). The second model observed average daily gain in the last four weeks at the facility (days 49-79). Calves that arrived at the veal rearing facility with a rectal temperature of 38.6-38.7°C gained 51g more per day than calves with a rectal temperature below 38.6°C ($P < 0.01$, 95% CI: 0.061 - 0.240kg/day). Calves that arrived in the spring and autumn months gained less than the calves that arrived in the winter months ($P = 0.05$). Within the overall average daily gain model, calves that entered the facility with a BMI $\geq 37.1$ g/cm$^2$ gained 82g more per day than calves that arrived with a BMI lower than 33.1 g/cm$^2$ ($P < 0.01$, 95% CI: 0.041 - 0.122kg/day). Additionally, calves that arrived with a rectal temperature of 38.6-38.7°C gained 58g more per day than calves with a lower rectal temperature ($P = 0.01$, 95% CI: 0.013 - 0.104kg/day). The BMI scale was compared to the animal’s length, height and weight on arrival in the model and the BMI proved have the most negative Bayesian Information Criterion, indicating that it fit the data better than the other similar variables. These results imply that the BMI, rectal temperature, and season of the calf on arrival to veal rearing facilities are important factors to pay attention to when it comes to healthy calves that are going to thrive.

INTRODUCTION

The profitability of a veal farm relies heavily on the growth of the calves, with higher growth rates leading to a higher revenue for the producer. Hence, it is imperative to have an understanding of factors that influence growth in order to maximize profitability. It is clear that
diseases occurring during the growing period have a significant impact on growth. Pardon et al. (2013) that demonstrated calves with bovine respiratory disease (BRD) or diarrhea at a veal calf facility had an 8.2 kg or 9.2 kg reduction in hot carcass weight, respectively. Similar effects have also been demonstrated in dairy heifer calves, with diarrhea, BRD, and umbilical infections leading to reduced calf performance (Windeyer et al., 2014; Virtala et al., 1996). However, these diseases occur once the calves have been purchased.

Identifying calves that will be at a growth disadvantage at arrival may allow for implementation of strategies to minimize the impact that growth disadvantages have on average daily gain. It has been shown in previous studies that many calves arrive at veal rearing facilities with identifiable health abnormalities and the health status at arrival at the milk-fed veal facility has been shown to influence the growth of calves (Renaud et al., 2018). Dehydration score, body weight at arrival, and season at arrival were associated with a reduced average daily gain (Renaud et al., 2018). However, this research was performed at a single milk-fed veal facility; more research is required to confirm study results and to explore additional risk factors influencing growth.

The objectives of this cohort study were to describe the health status of calves upon arrival at a grain-fed veal facility and to associate characteristics of the arriving calf with average daily gain (ADG).

Data were collected from a grain-fed veal rearing facility in southwestern Ontario, Canada from January to December 2017. This facility was selected based on an established relationship with, and proximity to, the University of Guelph. The study was conducted in accordance with University of Guelph Animal Care Committee requirements (Animal Use Protocol: #3695).

**MATERIALS AND METHODS**

Calves were transported to this facility from local dairy farms or from auction. Upon arrival at the facility, a single graduate student who had been trained by a veterinarian examined all calves using a standardized health scoring system. Facility staff weighed the calves using a Tru-Test™ digital weigh scale. All of the animals were vaccinated with an intranasal bacterin (Once PMH® IN) and an intranasal viral vaccine (Bovillis® IN). Calves were fed a milk replacer diet for 49 days before transitioning onto a grain-based diet following weaning. Calves
were housed individually for the first 21 days after arrival, in stalls with slatted rubber flooring. Following the initial 21-day acclimatization period, the partitions were removed, and calves were housed in groups of 5. After 11 weeks, the calves were transported to a larger group housing facility where they were housed for an additional 20 weeks, until slaughter. Data were not captured beyond 11 weeks as the larger group housing facility was deemed not to have reliable records.

Weight and treatment records were obtained from the producer and were used for analysis. Throughout the growing phase, calves were weighed at day 49 and day 79 following arrival, the date of weights were pre-determined by the producer. Heifer calves and beef cross calves were excluded from the dataset due to their low numbers. The facility had 4 rooms, each room with the capacity to hold up to 80 calves. Each group of calves in a room at one time was considered a ‘lot’, and this was used as a grouping variable in the analysis. A total of 14 lots were observed over this time frame.

**Standardized health scoring system**

An iPad (Apple Inc., Cupertino, CA) with the Calf Health Scorer app (University of Wisconsin-Madison, Madison, WI) and Qualtrics™ (http://www.qualtrics.com/) was used to facilitate the health scoring. The respiratory system (nose, eye, ear, cough; McGuirk and Peek, 2014), attitude, fecal consistency (McGuirk, 2008), navel inflammation (adapted from Fecteau et al., 1997), joint swelling, and rectal temperature were evaluated using the Calf Health Scorer app. Both fecal and navel score were re-categorised into 3 levels by combining the normal and slightly abnormal scores into a single group. This was done to reduce the likelihood for misclassification, as the criteria for these scores were considered ambiguous. Fecal score was categorized into 1: normal semi formed, 2: loose but stays on top of bedding, 3: watery and sifts through bedding, whereas, navel score was also categorized into 3 levels; 1: normal-slightly warm but not warm or painful, 2: swelling with pain or heat, slight lameness, and 3: swelling with severe pain, heat and lameness. Attitude score was collapsed into two categories as the dull or depressed category only contained 7 animals. Collapsing of these data into two categories for attitude represented a bright and alert calf as a 0 and a dull or depressed animal as 1. Similarly, other variables such as rectal temperature that did not have sufficient animals in a represented category were combined with the next closest category to allow for better data distribution. A Qualtrics form was used to collect body condition score (BCS) (Wilson et al., 2000), the
presence of a sunken flank (Bähler et al., 2012), and the level of clinical dehydration (Wilson et al., 2000). Additional information collected using the Qualtrics survey included: hip height (cm), length (cm) of the calf’s withers to lumbosacral junction, and navel diameter (mm) defined as the circumference at the base of the calf’s umbilicus. Body mass index (BMI) was calculated using weight on arrival (g) divided by the sum of the calf’s length from withers to lumbosacral junction and hip height (Mei et al., 2002). This allowed for a more objective score when compared to potential subjectivity of body condition scoring.

**Blood Collection**

Blood was collected from each calf at arrival via the jugular vein into a 10 ml sterile blood collection tube without an anticoagulant (BD Vacutainer; Becton, Dickson and Co., Franklin Lakes, NJ, USA). Blood was allowed to clot and then centrifuged at $1,500 \times g$ for 15 minutes at approximately 20°C. Serum was separated and serum total protein (STP) was evaluated using a digital refractometer (Misco® Palm Abbe™ #PA202x).

**Sample Size Calculation**

The number of calves enrolled in this study was based on a proportion estimation sample size calculation used to determine the required number of calves to determine a change in morbidity as it was the primary outcome of this study. Based on previous work by Pardon et al. (2015) and Renaud et al. (2018), a proportion estimation sample size calculation was used and it was estimated that calves identified on arrival with a health abnormality would have a morbidity risk of 26% whereas those without an abnormality would have a morbidity risk of 17%. Using 95% confidence interval and 80% power, a sample size of 916 calves was required.

**Statistical Analysis**

All statistical analyses were conducted using Stata 14 (StataCorp LP, College Station, TX). Data were imported from Microsoft Excel (Microsoft®; Redmond, WA) into Stata 14 and checked for completeness. A causal diagram (Figure 3.1) was created to illustrate the hypothesized relationships among the dependent and independent variables and was used to guide the analyses. Descriptive statistics were generated for all explanatory variables in the dataset.

A total of three mixed linear regression models were built for average daily gain (ADG), controlling for lot as a random effect. Controlling for each lot allowed for each room to be
observed as an individual population, and control for unmeasured confounders that may be related to the management of the lot. The ADG outcomes included; ADG within the first 49 days, ADG between 49-79 days, and ADG during the entire 79 days at the facility. The ADG was calculated by subtracting the calf’s weight at the beginning of the period from the final weight taken at the end of the time frame (49 days, and 79 days), and dividing by the number of days in the period. A lowess smoothing curve was generated to assess the linearity of each continuous predictor variable to the outcome. If a variable failed to meet the linearity assumption, the variable was categorized into quartiles. Based on this assessment, navel diameter was categorized into quartiles. Spearman rank coefficients were used to determine collinearity among the variables. If the correlation coefficient between 2 variables was ≥ 0.8, only one variable was retained, based on the fewest missing values, reliability of the measurement and biological plausibility. Explanatory variables that were unconditionally associated (P-value < 0.2) with the outcome in univariable mixed linear regression models were offered to a multivariable model through a manual backward stepwise removal process. For all variables of interest, a P-value ≤ 0.05 was used to assess significance. All possible interaction terms were individually tested for significance in the main effects model. A significant interaction was determined by a coefficient with a P-value ≤ 0.05. Only significant terms were included in the final model. If not significant, predictor variables were tested for confounding based on a 20% change between the crude and adjusted coefficients. If the difference in the coefficient of a significant variable between the reduced and full model was > 20% and was not an intervening variable identified in the causal diagram, the variable was considered a confounder and was kept in the model regardless of statistical significance. If there was < 20% change, no confounding was present, and that predictor was removed from the model. Homoscedasticity of the best linear unbiased predictions (BLUP’s) was assessed using standardized residuals. A scatter plot of the standardized residuals was examined to assess for patterns in the data such as fanning or coning. The normality of the residuals was assessed visually using quartile normal plots. Standardized residuals were also graphically plotted against predicted outcomes to assess for influential observations on the model. If any residuals were determined to be an extreme outlier, had high leverage, or was greatly influential, they were examined for recording errors and assessed to see if removal was be warranted.
RESULTS

**Descriptive Statistics**

A total of 14 lots of calves were assessed from January to December 2017. The minimum and maximum number of calves assessed in a lot was 40 and 82 calves, respectively, for the 14 lots. The age of these calves at arrival was unknown but the average age was suspected to be between 3 to 7 days. Calves were assessed throughout each season with the majority of calves being sampled in the spring (39.8% n = 397), followed by summer (22.5% n = 225), autumn (20.5% n = 205), and winter (17.1% n = 171). The average body weight of calves at arrival was 47.0 kg (n = 992). Throughout the duration of the 79 days, 992 calves were weighed at arrival, 636 at day 49, and 915 on day 79. The mortality rate in the last phase of weaning was 1.4% (n = 7) which is reflected by a reduction of the number of observations between day 79 and day 49. The overall mortality risk for 0-49 days is 5.8% (n = 50). Group treatment was administered to 35.1% (n = 348) of the calves, however there was no significant association between group treatment and ADG on any level. Descriptive statistics for the 15 explanatory variables can be found in Table 3.2 and 3.3 for health variables.

**Average Daily Gain**

A total of 915 animals had ADG calculated between the day of arrival and seven weeks into the facility. The explanatory variables included in the main effects model for 49-day ADG were cough score, season of entry, navel diameter, and BMI. In the final model, cough score was removed, and navel dimeter was found to be a confounder to BMI. Calves that entered the facility with a BMI ≥ 371 g/cm² gained 73 g more per day than calves that arrived with a BMI lower than 330 g/cm² (P < 0.01 (95% Confidence Interval: 0.011kg/day to 0.033 kg/day)). Calves that entered the facility during the spring months (March-May) gained 198g more per day than calves that entered in the other months (P = 0.01 (95% Confidence Interval: 0.0441kg/day to 0.3529 kg/day)) as illustrated in Table 3.4.

Average daily gain from day 49 to 79 was 1.20kg/day ± 0.39 kg/day. A total of 619 calves were used for the calculation of ADG in this phase at the facility. Four explanatory variables were associated with ADG in the final multivariable model, season, rectal temperature, serum total protein and BMI. Calves that arrived at the veal rearing facility with a rectal temperature of 38.6 to 38.8°C gained 150g per day more than calves that arrived with a rectal
temperature that was < 38.6°C (P <0.01, 95% CI: 0.061 to 0.24 kg/d). Calves that arrived at the facility during the spring and autumn months gained 226-250 g/day less than calves that arrived in the winter as seen in Table 3.5. Body mass index and serum total protein concentration were kept in the model as they confounded one another.

An overall ADG model was created to examine the factors that were associated with ADG over the entire pre-weaning period, 915 calves were observed. Navel diameter, rectal temperature, serum total protein, cough induced by tracheal stimulation and BMI were associated with ADG in univariable analysis. After manual backward selection, the final model contained rectal temperature, navel diameter, and BMI. Calves that arrived at the facility with a rectal temperature between 38.6 and 38.8°C gained 58g/day more than calves with a rectal temperature below 38.8°C (P = 0.01, 95% CI: 0.013 to 0.104). Calves with a BMI ≥ 371g/cm² gained 82g/day more than calves that arrived with a BMI < 331g/cm² (P < 0.01, 95% CI: 0.041 to 0.122), and navel diameter was kept in the model as a confounder as seen in Table 3.6.

**DISCUSSION**

This study suggests that the average daily gain of calves is associated with BMI, rectal temperature and season that the calves enter the facility. A limitation to consider is that the majority of these calves were selected at the source dairy farm of origin by the producer, allowing for selection bias to potentially occur as calves that appeared to be healthy may have been preferentially selected compared with any calves showing visible health concerns. This does not represent the majority of the veal facilities within Canada as calves are often bought at auction where producers are unable to have such selective parameters.

Body mass index was associated with growth in each period examined. This measure, based on work in humans (Mei et al, 2002), was developed to quantify the true weight and shape of the calf as looking at weight or size alone does not give an accurate depiction of the calf. Body mass index could reflect the age of the animal on arrival to the facility (Winder et al., 2016), with older calves having an advantage over younger smaller calves. In addition, calves with higher BMI could reflect the nutritional status of the animal on arrival (Winder et al., 2016), and management practices at the farm of origin.

Interestingly, rectal temperature has previously been shown to help improve diagnosis subclinical respiratory disease (McGuirk, 2011). Studies have demonstrated that neonatal calves
are not able to effectively regulate body temperature when exposed to extreme weather conditions, where, extreme weather induces hypo or hyperthermia resulting in immune system impairment (Mee, 2004). This increased susceptibility to disease may indirectly contribute to reduced ADG. This theory indicates the importance of proper ventilation and temperature throughout the facility to enhance ADG. It has been noted that calf caloric is particularly important during the summer and winter months due to increased body maintenance energy costs for keeping warm and cool (Moore et al., 2012). If calves with a lower BMI in the study did not consume enough then they would be at higher risk for morbidity, mortality and decreased ADG. Proper nutrition to allow for proper thermoregulation is crucial for young calves adapting in a new environment. However, in this study calves that arrived in the spring and autumn months gained less than calves that entered in the winter which may be due to the heating system in the barn which maintains temperature at a specific level.

Group oral antibiotic therapy upon arrival at veal operations remains a standard protocol in Canada and across Europe (Jarrige et al., 2017; Pardon et al., 2012). It was interesting to note that the provision of oral antimicrobials for the initial portion of the growing period was not significant in any of the models evaluating ADG. Conversely, Rérat et al. (2012) and Berge et al. (2005) found that prophylactically treated calves for the first days after arrival at the veal rearing facility resulted in higher ADG compared to calves that were not treated at all. However, contrasting results are presented by Berge et al. (2009), where no differences in gain were observed between calves treated orally with antibiotics and those receiving no treatment. Due to pressure surrounding antimicrobial use, the industry needs to explore the necessity and effectiveness of group antibiotic therapy (Jarrige et al., 2017) as it represents the majority of antimicrobial consumption in veal enterprises (Lava et al., 2016; Jarrige et al., 2017; Pardon et al., 2012).

**CONCLUSION**

Observing the health status of calves at arrival to a veal rearing facility can aid in identifying calves that could have a higher average daily gain. Selecting solely calves that have a BMI of approximately 371 g/cm² and calves with a rectal temperature of 38.6-38.7°C could lead to an increased ADG on the farm and would greatly improve the economics of this industry. However, as the prevalence of the health abnormalities at arrival is significant, this may not be a
practical strategy and future work should explore how to prevent the irregularities from occurring before the calves arrive to the facility through proper management techniques at the farm of origin.

REFERENCES


Table 3.1. Description, number of observations, mean, and standard deviation of average daily gain occurring over the growing period.

<table>
<thead>
<tr>
<th>Description</th>
<th>Number Observations</th>
<th>Mean ADG</th>
<th>Standard Deviation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Average daily gain 0 - 49 days</td>
<td>636</td>
<td>0.61</td>
<td>0.23</td>
</tr>
<tr>
<td>Average daily gain 49 - 79 days</td>
<td>619</td>
<td>1.19</td>
<td>0.40</td>
</tr>
<tr>
<td>Average daily gain 0 - 79 days</td>
<td>915</td>
<td>0.86</td>
<td>0.23</td>
</tr>
</tbody>
</table>
Table 3.2. Frequency and prevalence of categorical variables measured on arrival at a grain-fed veal facility.

<table>
<thead>
<tr>
<th>Variable Name</th>
<th>Description</th>
<th>Frequency</th>
<th>Prevalence</th>
</tr>
</thead>
<tbody>
<tr>
<td>Attitude</td>
<td>Bright, alert, and responsive</td>
<td>918</td>
<td>92.0%</td>
</tr>
<tr>
<td></td>
<td>Dull &amp; Depressed</td>
<td>80</td>
<td>8.0%</td>
</tr>
<tr>
<td>Nasal Discharge</td>
<td>Normal, serous discharge</td>
<td>996</td>
<td>99.8%</td>
</tr>
<tr>
<td></td>
<td>Small amount of unilateral, cloudy discharge</td>
<td>2</td>
<td>0.2%</td>
</tr>
<tr>
<td>Ear Position</td>
<td>Normal</td>
<td>956</td>
<td>95.8%</td>
</tr>
<tr>
<td></td>
<td>Ear flicking</td>
<td>39</td>
<td>3.9%</td>
</tr>
<tr>
<td></td>
<td>Slight unilateral ear drop</td>
<td>3</td>
<td>0.3%</td>
</tr>
<tr>
<td>Ocular Discharge</td>
<td>Normal</td>
<td>940</td>
<td>94.2%</td>
</tr>
<tr>
<td></td>
<td>Mild ocular discharge</td>
<td>55</td>
<td>5.5%</td>
</tr>
<tr>
<td></td>
<td>Moderate bilateral ocular discharge</td>
<td>2</td>
<td>0.2%</td>
</tr>
<tr>
<td></td>
<td>Heavy ocular discharge</td>
<td>1</td>
<td>0.1%</td>
</tr>
<tr>
<td>Cough Score</td>
<td>No cough</td>
<td>906</td>
<td>90.8%</td>
</tr>
<tr>
<td></td>
<td>Induce single cough</td>
<td>92</td>
<td>9.2%</td>
</tr>
<tr>
<td>Fecal</td>
<td>Normal &amp; Semi-formed, pasty</td>
<td>863</td>
<td>86.5%</td>
</tr>
<tr>
<td></td>
<td>Loose, but stays on top of bedding</td>
<td>75</td>
<td>7.5%</td>
</tr>
<tr>
<td></td>
<td>Watery, sifts through bedding</td>
<td>60</td>
<td>6.0%</td>
</tr>
<tr>
<td>Navel</td>
<td>Normal &amp; Slightly enlarged, not warm or painful</td>
<td>799</td>
<td>80.1%</td>
</tr>
<tr>
<td></td>
<td>Slightly enlarged with slight pain or moisture</td>
<td>170</td>
<td>17.0%</td>
</tr>
<tr>
<td></td>
<td>Enlarged with pain, heat or malodorous discharge</td>
<td>29</td>
<td>2.9%</td>
</tr>
<tr>
<td>Dehydration</td>
<td>&lt; 5% dehydrated</td>
<td>623</td>
<td>87.9%</td>
</tr>
<tr>
<td></td>
<td>5 to 7% dehydrated</td>
<td>47</td>
<td>6.6%</td>
</tr>
<tr>
<td></td>
<td>&gt; 7% dehydrated</td>
<td>39</td>
<td>5.5%</td>
</tr>
<tr>
<td>Group treatment</td>
<td>No</td>
<td>645</td>
<td>64.9%</td>
</tr>
<tr>
<td>administered at arrival</td>
<td>Yes</td>
<td>348</td>
<td>35.1%</td>
</tr>
</tbody>
</table>
Table 3.3. Mean and standard deviation of continuous variables measured on arrival at a grain-fed veal facility.

<table>
<thead>
<tr>
<th>Variable Name</th>
<th>Description</th>
<th>Mean</th>
<th>Standard Deviation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Length (cm)</td>
<td>Length from withers to lumbar sacral junction</td>
<td>46.83</td>
<td>2.86</td>
</tr>
<tr>
<td>Height (cm)</td>
<td>Calf hip height</td>
<td>86.69</td>
<td>3.36</td>
</tr>
<tr>
<td>Navel Diameter (mm)</td>
<td>Diameter of calf's navel</td>
<td>25.37</td>
<td>8.99</td>
</tr>
<tr>
<td>Weight on Arrival (kg)</td>
<td>Weight on arrival</td>
<td>46.96</td>
<td>4.84</td>
</tr>
<tr>
<td>Serum Total Protein (g/dL)</td>
<td>Serum Total Protein</td>
<td>5.76</td>
<td>0.66</td>
</tr>
<tr>
<td>Body Mass Index (g/cm²)</td>
<td>BMI</td>
<td>351.56</td>
<td>32.07</td>
</tr>
</tbody>
</table>
Table 3.4. Results of final mixed linear regression model evaluating risk factors for average daily gain in kg/day in the first 49 days at a veal rearing facility.

<table>
<thead>
<tr>
<th>Variable</th>
<th>Description</th>
<th>Coefficient</th>
<th>P-Value</th>
<th>95% Confidence Interval</th>
<th>Prevalence</th>
</tr>
</thead>
<tbody>
<tr>
<td>Body Mass Index (g/cm²)</td>
<td>&lt;330</td>
<td>Referent</td>
<td></td>
<td></td>
<td>24.80% (n = 246)</td>
</tr>
<tr>
<td></td>
<td>331-349</td>
<td>0.026</td>
<td>0.23</td>
<td>(-0.017, 0.069)</td>
<td>24.90% (n = 247)</td>
</tr>
<tr>
<td></td>
<td>350-371</td>
<td>0.026</td>
<td>0.22</td>
<td>(-0.016, 0.069)</td>
<td>24.90% (n = 247)</td>
</tr>
<tr>
<td></td>
<td>372</td>
<td>0.073</td>
<td>&lt;0.01</td>
<td>(0.031, 0.115)</td>
<td>25.40% (n = 252)</td>
</tr>
</tbody>
</table>
Table 3.5. Results of final mixed linear regression model evaluating risk factors for average daily gain in kg/day in the last 30 days at a veal rearing facility.

<table>
<thead>
<tr>
<th>Variable</th>
<th>Description</th>
<th>Coefficient</th>
<th>P-Value</th>
<th>95% Confidence Interval</th>
<th>Prevalence</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rectal Temperature (°C)</td>
<td>&lt;38.6</td>
<td>Referent</td>
<td></td>
<td></td>
<td>25.85% (n = 258)</td>
</tr>
<tr>
<td></td>
<td>38.6 - 38.7</td>
<td>0.150</td>
<td>&lt;0.01</td>
<td>(0.061, 0.240)</td>
<td>15.63% (n = 156)</td>
</tr>
<tr>
<td></td>
<td>38.8 - 39.1</td>
<td>0.027</td>
<td>0.52</td>
<td>(-0.054, 0.107)</td>
<td>25.75% (n = 257)</td>
</tr>
<tr>
<td></td>
<td>&gt; 39.2</td>
<td>0.051</td>
<td>0.19</td>
<td>(-0.026, 0.129)</td>
<td>32.77% (n = 327)</td>
</tr>
<tr>
<td>Season</td>
<td>Winter</td>
<td>Referent</td>
<td></td>
<td></td>
<td>17.13% (n = 171)</td>
</tr>
<tr>
<td></td>
<td>Spring</td>
<td>-0.245</td>
<td>0.05</td>
<td>(-0.492, 0.002)</td>
<td>39.78% (n = 397)</td>
</tr>
<tr>
<td></td>
<td>Summer</td>
<td>-0.050</td>
<td>0.70</td>
<td>(-0.298, 0.199)</td>
<td>22.55% (n = 225)</td>
</tr>
<tr>
<td></td>
<td>Autumn</td>
<td>-0.225</td>
<td>0.05</td>
<td>(-0.45, -0.001)</td>
<td>20.54% (n = 205)</td>
</tr>
<tr>
<td>Body Mass Index (g/cm²)</td>
<td>&lt;330</td>
<td>Referent</td>
<td></td>
<td></td>
<td>24.80% (n = 246)</td>
</tr>
<tr>
<td></td>
<td>331-349</td>
<td>-0.039</td>
<td>0.36</td>
<td>(-0.122, 0.044)</td>
<td>24.90% (n = 247)</td>
</tr>
<tr>
<td></td>
<td>350-371</td>
<td>0.020</td>
<td>0.63</td>
<td>(-0.063, 0.104)</td>
<td>24.90% (n = 247)</td>
</tr>
<tr>
<td></td>
<td>372</td>
<td>0.067</td>
<td>0.11</td>
<td>(-0.014, 0.149)</td>
<td>25.40% (n = 252)</td>
</tr>
<tr>
<td>Serum Total Protein (g/dL)</td>
<td>&lt;5.3</td>
<td>Referent</td>
<td></td>
<td></td>
<td>22.09% (n = 209)</td>
</tr>
<tr>
<td></td>
<td>5.3 - 5.6</td>
<td>-0.009</td>
<td>0.83</td>
<td>(-0.09, 0.072)</td>
<td>31.18% (n = 295)</td>
</tr>
<tr>
<td></td>
<td>5.7 - 6.1</td>
<td>0.042</td>
<td>0.33</td>
<td>(-0.043, 0.127)</td>
<td>25.37% (n = 240)</td>
</tr>
<tr>
<td></td>
<td>&gt; 6.2</td>
<td>0.053</td>
<td>0.24</td>
<td>(-0.035, 0.141)</td>
<td>21.35% (n = 202)</td>
</tr>
</tbody>
</table>
Table 3.6. Results of final mixed linear regression model evaluating risk factors for average daily gain in kg/day in 79 days at the veal rearing facility.

<table>
<thead>
<tr>
<th>Variable</th>
<th>Description</th>
<th>Coefficient</th>
<th>P-Value</th>
<th>95% Confidence Interval</th>
<th>Prevalence</th>
</tr>
</thead>
<tbody>
<tr>
<td>Body Mass Index (g/cm²)</td>
<td>&lt;330</td>
<td>Referent</td>
<td></td>
<td></td>
<td>24.80% (n = 246)</td>
</tr>
<tr>
<td></td>
<td>331-349</td>
<td>0.020</td>
<td>0.34</td>
<td>(-0.021, 0.061)</td>
<td>24.90% (n = 247)</td>
</tr>
<tr>
<td></td>
<td>350-371</td>
<td>0.023</td>
<td>0.26</td>
<td>(-0.017, 0.063)</td>
<td>24.90% (n = 247)</td>
</tr>
<tr>
<td></td>
<td>372</td>
<td>0.082</td>
<td>&lt;0.01</td>
<td>(0.041, 0.122)</td>
<td>25.40% (n = 252)</td>
</tr>
<tr>
<td>Navel Diameter (mm)</td>
<td>&lt;19.43</td>
<td>Referent</td>
<td></td>
<td></td>
<td>25.17% (n = 225)</td>
</tr>
<tr>
<td></td>
<td>19.43 - 23.45</td>
<td>-0.014</td>
<td>0.50</td>
<td>(-0.054, 0.026)</td>
<td>25.28% (n = 226)</td>
</tr>
<tr>
<td></td>
<td>23.46 - 29.24</td>
<td>-0.030</td>
<td>0.15</td>
<td>(-0.071, 0.011)</td>
<td>25.17% (n = 225)</td>
</tr>
<tr>
<td></td>
<td>&gt;29.25</td>
<td>0.025</td>
<td>0.25</td>
<td>(-0.018, 0.068)</td>
<td>24.38% (n = 218)</td>
</tr>
<tr>
<td>Rectal Temperature (°C)</td>
<td>&lt;38.6</td>
<td>Referent</td>
<td></td>
<td></td>
<td>25.85% (n = 258)</td>
</tr>
<tr>
<td></td>
<td>38.6 - 38.7</td>
<td>0.058</td>
<td>0.01</td>
<td>(0.013, 0.104)</td>
<td>15.63% (n = 156)</td>
</tr>
<tr>
<td></td>
<td>38.8 - 39.1</td>
<td>0.011</td>
<td>0.61</td>
<td>(-0.030, 0.051)</td>
<td>25.75% (n = 257)</td>
</tr>
<tr>
<td></td>
<td>&gt; 39.2</td>
<td>0.019</td>
<td>0.32</td>
<td>(-0.019, 0.057)</td>
<td>32.77% (n = 327)</td>
</tr>
</tbody>
</table>
Figure 3.1. Causal diagram describing the relationship of measured variables to the outcome average daily gain.
CHAPTER 4
GENERAL CONCLUSIONS AND LIMITATIONS

The purpose of the research studies described in this thesis were to explore health abnormalities that were present in calves as they arrived at a grain-fed veal rearing facility and the associations with morbidity, mortality, and average daily gain. In its entirety, this work demonstrated that a significant number of veal calves are entering the Canadian veal industry with health abnormalities impacting their short and long-term welfare.

The first objective, explored in Chapter 2, was to describe the health of the calves arriving at one grain-fed veal facility and the associations with the short and long-term morbidity, and mortality. This work is one of very few studies that has investigated morbidity in calves at a veal rearing facility in Canada. In the first 21 days following arrival, 676 calves (68.3%) were treated at least once, with 420 calves (42.1%) and 501 calves (50.2%) being treated for diarrhea and pneumonia, respectively. A total of 877 (88.6%) of calves were treated at least once over the 11-week housing period at the grain-fed veal facility. Calves that arrived with a body mass index > 371 g/cm² were less likely to be treated than calves with a BMI of 330 g/cm². A total of 75 calves (7.5%) died over the 11-week period of observation at this facility. Calves that arrived at the facility with a fecal score of 2 were more likely to die. Calves that had a body mass index of > 371 g/cm² were less likely to die than calves that had a body mass index of < 330 g/day.

The location of the veal rearing facility was selected due to proximity and the relationship it has with the University of Guelph. As the producer selected calves from the source dairy farms, there could be some selection bias as the driver could choose older calves, or healthier looking calves. This does not accurately represent the majority of the North American veal industry as calves are often purchased from auction. Despite the potential biases present, Chapter 2 provides insight into the health abnormalities that are found at veal rearing facilities creating potential avenues to improve certain management practices and ultimately advance the health and welfare of male calves.

The second objective was to describe the health status of calves arriving at a grain-fed veal facility and to associate characteristics of the arriving calf with ADG. In Chapter 3, a prospective cohort study was able to explore this particular objective. Based on the results of this study, BMI >372 g/cm², rectal temperature between 38.6-38.7°C, spring and autumn seasons
were associated with ADG. This is one of few studies that looks at the health status of the calves as they arrive at the veal rearing facility and the factors that are associated with ADG. A total of 14 lots of calves were assessed from January to December 2017. The multivariable model that assessed ADG from day 0-49 found that calves that entered the facility with a BMI \( \geq 371 \text{ g/cm}^2 \) gained 75g more per day than calves that arrived with a BMI \(< 331 \text{ g/cm}^2 (P < 0.01 (95\% \text{ Confidence Interval: 0.011kg/day to 0.033 kg/day})). Calves that entered the facility during the spring months (March-May) gained 198g more per day than calves that entered in the other months \((P = 0.01 (95\% \text{ Confidence Interval: 0.0441kg/day to 0.3529 kg/day}))\). Within the model for ADG of calves after weaning, days 49-79 it was found that calves that arrived at the veal rearing facility with a rectal temperature of 38.6-38.8°C gained 150g/day more than calves that arrived with a rectal temperature that was \(< 38.6-38.8°C. Calves that arrived at the facility during the spring and autumn months gained 226-250g/day less than calves that arrived in the winter. Within the overall ADG model that observed calves over 11 weeks, calves that arrived at the facility with a rectal temperature between 38.6 and 38.8°C gained 58g/day more than calves with a rectal temperature below 38.8°C. Calves with a BMI \( \geq 371\text{ g/cm}^2 \) gained 82g/day more than calves that arrived with a BMI \(< 331\text{ g/cm}^2 \).

Similarly, to Chapter 2 location impacts the relatability this study has with veal production facilities across North America. Selection bias is also plausible as the producer picks up the calves from the source of origin, allowing for selection bias to occur. The producer does not have to pick the calves up if they do not meet his requirements. There is the potential to pick up healthier, and older calves than what is normally selected at an auction mart. Even when taking into consideration the potential biases, Chapter 3 provides unique insight to the health abnormalities that are found in calves upon arrival and the associations they have to ADG. This insight allows for on arrival screening to pick up health implications sooner and allows for healthier calves faster.

**FUTURE WORK**

Antimicrobial use, morbidity, and mortality are all major concerns in the North American veal industry. With health and welfare being important to support the sustainability of the veal industry, action must be taken to reduce morbidity, and mortality levels and decrease a reduction
in ADG. The work described in this thesis identifies several risk factors associated with morbidity, mortality, and reduction in ADG and could focus attention on some key areas for intervention, and more importantly prevention of disease in male calves.

Simply recreating this study in an alternate geographical location or within a typical veal herd that is commonly found in North America would enhance the reliability of the findings of this study. To date, very few studies have been performed in North America on grain-fed veal calves.

The true impact that transportation has on these calves is unknown. It may prove to be effective to observe the true effect that transport has on these calves. Determining if where the calves are located within the trailer impacts the journey. The amount of time the calves are in the trailer in extreme weather conditions could also be explored. Previous studies have investigated the effect of feed withdrawal prior to transport (Todd et al., 2000), determining that food withdrawal prior to transport negatively impacts the calves post transport, leading to increased morbidity and mortality. Since animals within North America will travel at some point in time in their life, it would be interesting to determine if there is a uniquely designed way of transporting livestock to reduce the amount of stress that is present, ultimately increasing the welfare of the animals during this process and increasing the economics of the livestock industry. The age at which calves are transported is another aspect that this study was unable to cover and is a topic that is not very well addressed within the industry. A study could be designed to determine the impact that transportation has on calves of various ages. The study would have to take into consideration the climate that the calves were travelling in and total time in the trailer.

It is incredibly common for producers to orally treat the entire calf herd on arrival (Pardon et al., 2012). Chapter 2 and 3 provide some health parameters to identify high-risk calves that can be evaluated quickly and easily by producers within the veal industry. Average daily gain, morbidity, and mortality could be monitored to determine if any improvements are made if calves that present with these health abnormalities on arrival are treated immediately. Previously, the livestock industry has been targeted for is over use and misuse of antimicrobials and the resistance developed (Pardon et al., 2014), this could provide a route to overcome this challenge. A potential solution could be that contracts are created with facilities that consistently pick up calves from source farms that provide healthy calves. This would allow for a deduction
of calves that arrive with specific health abnormalities. This solution could force producers to ensure that their veal calf candidates are nutritionally sound, as well as physically sound.

REFERENCES


