PREDICTING HEALTH OUTCOMES AND SALE PRICE OF MALE DAIRY CALVES UNDERGOING LONG DISTANCE TRANSPORTATION

by

Devon Wilson

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Examining Committee:

Dr. David Fraser
Supervisor

Dr. Dan Weary
Supervisory Committee Member

Dr. Chelsea Himsworth
Additional Examiner

Additional Supervisory Committee Members:

Dr. David Renaud
Supervisory Committee Member

Abstract

Male dairy calves are often marketed at a young age when they are vulnerable to health and welfare problems. This study described the condition of male dairy calves before transportation and evaluated factors associated with selling price at an auction market and health outcomes at two calf-rearing facilities (calf growers). Male calves were evaluated at their dairy farm of origin, at an auction market, and after long-distance transportation to a calf grower. Measures of calf condition included a standardized health examination, age, heart girth circumference (HG), and serum total protein as an indication of failure of transfer of passive immunity (FTPI). Selling price at the auction, and treatments for diarrhea or bovine respiratory disease (BRD), along with all mortalities, were recorded during the first 2 wk after arrival at a calf grower. A McNemar Test was used to determine if health deteriorated after transportation and regression analysis was used to evaluate the effects of calf condition on selling price and health outcomes. Large variation in calf condition before transportation was found among dairy farms, with a median prevalence of 17% diarrhea, 2% BRD, 9% navel disease, and 12% FTPI. Calves were transported at a median (interquartile range) age of 5 (3-7) d, with a mean ± SD heart girth circumference of 82 ± 4 cm. Calves observed at auction market with beef genetics that had a large HG and bright, alert attitude sold for a higher price. Immediately after transportation to the calf grower, a greater proportion of calves had an elevated body temperature and a lower proportion had diarrhea, possibly due to dehydration. Calves with FTPI were more likely to develop a depressed attitude after transportation. In the first 2 wk after arrival, 23% of calves were treated for diarrhea, 44% were treated for BRD, and 3.9% died. Important risk factors for diarrhea treatment included small HG and navel disease, and calves with a depressed attitude were more likely to die. These findings indicate there is a need for improvement in the condition of male dairy calves to protect their health and welfare and increase their economic value.

Lay Summary

The management of male dairy calves is a growing animal welfare concern in the dairy sector, and recently scientists have found calves are sold at a young age and sometimes arrive at calf farms in poor condition. This study evaluated male dairy calves before they were removed from their farm of origin. Most calves were sold around 5 days old, and some showed signs of diarrhea, pneumonia and navel disease. Male dairy calves with beef genetics that were large and healthy were sold for higher prices at an auction. Calves that were transported at a light weight and with navel disease were more likely to be treated for diarrhea, and calves that had a bright attitude were less likely to die at the calf farm. This study provides useful information to help farmers determine which calves are more likely to receive a higher price and do well at calf farms.

Preface

I completed this study with supervision from Dr. David Fraser from the University of British Columbia. My supervisory committee additionally included Dr. Dan Weary and Dr. David Renaud from the University of British Columbia and the University of Guelph, respectively.

The studies presented in this thesis were approved by the University of British Columbia's Animal Care Committee (#A16–0336-001). The animals were cared for according to the guidelines outlined by the Canadian Council of Animal Care (2009).

Chapters 2 and 3 were co-authored with D. Fraser, D. Weary and J. Stojkov from the University of British Columbia and D. Renaud from the University of Guelph. The research questions and study design were developed with the supervisory committee and Jane Stojkov, who also assisted in data analysis and interpretation and provided editorial comments on the manuscript. I was responsible for conducting the study.

A version of chapter 2 is being prepared for publication. D.J. Wilson designed the study in collaboration with the co-authors, collected all data, and wrote the manuscript. J.S. Stojkov and D.L. Renaud helped with study design, data analysis and interpretation, and D. Fraser acted in the typical role of supervisor, helping with study design, statistical analysis, input and editing of manuscript drafts. The project received UBC Animal Care Approval (certificate number: A16-0336-001).

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List of Abbreviations

AIC: Akaike information criterion

BC: British Columbia

BRD: Bovine Respiratory Disease

BW: body weight

CG: calf grower

CI: confidence interval

cm: centimeters

d: day(s)

EU: Europe

FTPI: failure of transfer of passive immunity

h: hour

HG: heart girth

IQR: interquartile range

kg: kilogram

SD: standard deviation

SE: standard error

STP: serum total protein

UBC: University of British Columbia

wk: week

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Thank you to my parents, Stacy and Alice Wilson for accepting that your daughter may never leave school. My roots help me see the work needing to be done, which gets me through every day as a veterinarian and researcher. Thank you to all my other family – I am grateful for the things you've handed down, and your consistent love and support.

Lastly, to my husband Eric, thank you for helping me balance all the important things in life. You help me stay organized, can build any gadget I need, and have sacrificed a simple 9 to 5 lifestyle to allow me to pursue my dream of becoming a researcher. Thanks for your patience and love during the first 2 years of marriage while I master this science thing.

To the calves and their farmers.

Chapter 1: Introduction

Male dairy calf health and welfare remains an important concern for the dairy and red meat industries. Transportation (Cave et al., 2005) and rearing practices (Bokkers and Koene, 2001) of young male dairy calves have been among the top concerns regarding dairy production in recent decades. Reflecting this societal concern, regulations regarding the care and transportation of calves have been updated recently in New Zealand (Ministry for Primary Industries, 2018), the European Union (European Union, 2005; Webb et al., 2013), and Canada (Canadian Food Inspection Agency, 2019). Unfortunately, little scientific research on calf transportation has been available to guide these regulations.

Dairy calves that will not be kept as replacements and are sold at a young age do not contribute considerably to farm profitability, and have been described as “a low value by-product of the dairy industry” (Cave et al., 2005). Perhaps as a result, the marketing system for male dairy calves may involve long-distance transportation, multiple loading and unloading events, and an extended time without access to food or water. Calves that are in good health sell for higher prices (Marquou et al., 2019), and low prices may influence a farmer’s decision to euthanize calves at birth (Renaud et al., 2017), suggesting that market conditions may affect male calf management at the dairy farm of origin. Further exploration of the factors influencing male dairy calf prices and the effect of low market value on calf welfare is warranted.

The importance of calf health status upon arrival at veal facilities has been emphasized by recent research that suggests heavier calves with healthy navels and adequate hydration have better health and growth (Renaud et al., 2018d; a). Identifying such factors is critical for preventing disease and mortality, as these are major welfare and economic limitations in the veal industry. Recent work has shown approximately a quarter of veal calves develop at least one disease and up to 10%, depending on the farm, die during the feeding period (Pardon et al., 2012a; Renaud et al., 2018c). Such challenges have led to high rates of antimicrobial use in the industry, and this has important human and animal health implications due to the increasing prevalence of antimicrobial resistance (Lava et al., 2016). Efforts to identify risk factors in calves have focused on their health upon arrival, but little work has evaluated male calf condition at their dairy farm of origin. Since many factors affecting calf health relate to early life management such as dystocia prevention, colostrum provision, and environmental cleanliness, investigation of the condition of calves before marketing and the relationship to subsequent health outcomes is an important research goal.

Along with the care calves receive at dairy farms, transportation conditions may also influence early health at veal facilities. Transportation can involve multiple stressors such as handling by unknown personnel, comingling with unfamiliar animals, exposure to extreme weather conditions, and food and water deprivation (Trunkfield and Broom, 1990). Season and duration of travel have also been shown to relate to poor outcomes such as weight loss and a drop in body temperature (Knowles et al., 1999) or higher mortality (Cave et al., 2005). Little recent work has attempted to identify health deterioration in calves under current transportation practices.

In this chapter, I will attempt to summarize what is known about male dairy calf marketing, and calf management and transportation factors that are associated with health outcomes at calf-rearing facilities. As my thesis is focused on predicting which calves are at risk for poor health outcomes, I will identify areas for improvement and gaps in research that need to be addressed to improve the quality of life of male dairy calves.

1.1 Marketing of Male Dairy Calves

Although advances in reproductive technology provide an option for dairy farmers to produce more female calves, the latest survey reported that male dairy calves still make up approximately 50% of the dairy calf crop (De Vries et al., 2008). While this has likely declined due to a rapid uptake of sexed semen (McCullock et al., 2013), surplus male dairy calves are still widely marketed. Market avenues for these male dairy calves vary regionally and over time, with calves being reared as a secondary commodity for dairy farms, or sold for bob veal slaughter, to veal producers, or to calf rearing facilities that supply the dairy beef industry. Currently, farms in Canada typically rear all their female dairy calves as potential replacements for the milking herd, and male calves typically are sold from their farm of origin when they are less than 2 wk old (Renaud et al., 2017).

Male dairy calves are marketed through many different avenues worldwide. In Eastern Canada, selling young male dairy calves through specialized auction markets has been reported in Quebec (Marquou et al., 2019). These calves likely enter milk- or grain-fed veal facilities where they will be fed for approximately 20 and 32 wk, respectively. Marketing calves through auctions was also reported by 61% of dairy farms in the USA (Shivley et al., 2019), where most calves would enter veal farms or “calf ranches” to supply beef feedlots (Walker et al., 2012). Veal farms may also source calves directly from local dairy farms, or through livestock transporters sometimes called “drovers” (Renaud et al., 2018d). Most male calves in Europe enter veal production systems which are highly integrated, with calves raised predominantly in France, the Netherlands and Italy (Brscic et al., 2011; Pardon et al., 2012a). In New Zealand and Australia, where a veal or dairy-beef market has not developed, calves are transported from dairy farms to slaughter facilities for “bob” or “bobby” veal production (Stafford et al., 2001; Cave et al., 2005). Bob veal is defined as calves sold directly from dairy farms for slaughter at 2 to 10 d (Wilson et al., 2000). Neonatal slaughter of dairy calves also occurs in Canada and likely elsewhere in the world, although the proportion of calves entering this market is unknown.

As most dairy farms do not want to raise male dairy calves as a secondary commodity, their fate depends on the development of local veal or dairy beef markets. As dairy-bred animals have lower feed efficiency and produce a less desirable carcass compared to beef cattle (Clarke et al., 2009), the price of dairy calves must be appreciably lower to remain competitive. Renaud et al. (2017) compiled data from 3 auctions in eastern Canada from 2013-2016 and found calves were sold within a wide range, between $30 and $530. These authors also noted “significant variability both within and between years in the price paid to Canadian producers for male calves”. During times when the market price is very low, farmer’s may elect to euthanize male calves at birth rather than sell them at a net loss, although this has not been systematically documented (Renaud et al., 2017). Elsewhere in the world, the price of male calves and the marketing strategies used by farmers have not been evaluated.

1.2 Welfare Problems for Male Dairy Calves

Disease and death are welfare and production-limiting problems in many calf rearing systems (Pardon et al., 2012a; Windeyer et al., 2014; Al Mawly et al., 2015). Much research has been devoted to identifying important risk factors and best management practices to improve calf health. Strategies include ensuring timely provision of adequate colostrum and milk, reducing dystocia, and providing clean and draft-free housing (Hulbert and Moisá, 2016). Beyond focusing on health and biological functioning, some management practices for male dairy calves impact their affective state and ability to perform natural behaviours, which are two important aspects of animal welfare (Fraser, 2008). Such practices include restrictive milk feeding, social isolation, and inappropriate housing systems (Vasseur et al., 2010). This introduction will attempt to summarize literature relevant to male dairy calf health and welfare on dairy farms, calf rearing facilities, and during transport and marketing.

1.2.1 At the Dairy Farm

Management practices and environmental conditions that predispose calves to developing disease often occur during the first week of life. A Canadian survey found male calves are generally sold under 2 wk old (Renaud et al., 2017); in the USA, male calves reportedly left the farm at a median age of 7.6 d (Shivley et al., 2019); and in Europe calves are transported at a minimum age of 14 d (European Union, 2005). Despite being on the farm of origin for a relatively short time, dairy farm management can have a large impact on subsequent veal calf health (Renaud et al., 2018c). For example, calves entering veal facilities are sometimes suffering from thin body condition, navel, respiratory or enteric disease, or failure of transfer of passive immunity (FTPI), which likely relate to dairy farm management (Wilson et al., 2000; Pempek et al., 2017). Poor arrival condition is concerning and can lead to reduced growth and increased mortality. Researchers have suggested that differences in the level of care for male and female dairy calves may be partly to blame for the poor condition of some male calves upon arrival at rearing facilities (Shivley et al., 2019). This section will review management practices on dairy farms that may influence the subsequent health and welfare of male dairy calves.

One of the first opportunities to safeguard calf health is to improve the management and prevention of dystocia. Dystocia, or a delayed or difficult parturition, can result in more stillborn calves. Researchers have found that 40% of males and 33% of heifer calves required interventions during calving, and 10% vs 6% (respectively) were stillborn (Lombard et al., 2007). If they do survive birth, calves that experience dystocia are more likely to die or be treated for respiratory or enteric disease (Lombard et al., 2007). The greater birthweight of male dairy calves likely contributes to their increased risk of dystocia (Johanson and Berger, 2003; Olson et al., 2009). As managing dystocia requires timely intervention (Mee, 2004), it is unsurprising that Renaud et al. (2018c) found farms that checked calving pens more frequently were less likely to be classified as high-mortality source farms based on the mortality of their male calves at a veal facility.

After calving, dipping the umbilicus in antiseptic solution is commonly recommended to promote healing and prevent infection (Fordyce et al., 2018). Despite this long-standing recommendation, only 40% of dairy producers in an Ontario study reported always dipping the navels of male calves (Renaud et al., 2017). Recent research on navel dipping has compared novel products to the commonly used 7% iodine tincture and found similar effectiveness (Wieland et al., 2017; Fordyce et al., 2018). Unfortunately, there is a paucity of published research on navel dipping using a negative control to help clarify the efficacy of the procedure and investigate interactions with other calf management practices. Interestingly, navel dipping has been associated with increased disease in dairy heifers (Windeyer et al., 2014). It is possible that providing clean, dry bedding in the calving and maternity pen may be a more effective way to prevent navel disease (Mee, 2004). Clarifying the best method for preventing navel infections is important as veal calves that arrive with navel disease are at higher risk for mortality (Renaud et al., 2018a).

Next to ensuring a successful calving, farms can greatly improve calf immunity by providing clean colostrum with a high immunoglobulin concentration, ideally within 4 hours after birth (Weaver et al., 2000). The importance of colostrum has been well known for decades (Frerking and Aeikens, 1978), and measuring FTPI is emphasized as an important step in promoting good health and growth in calves (Atkinson et al., 2017). Despite the extensive research and education on the importance of good colostrum management, recent reports found 9% of Canadian farms did not always give bull calves colostrum (Renaud et al., 2017), and on average, farms in the USA reported that 3.7% of male calves did not receive colostrum (Shivley et al., 2019). Shivley et al. (2019) also reported differences in colostrum management between heifers and bulls, with bulls receiving less colostrum in the first 24 hours, at a slightly later time after birth, and more male calves received colostrum through suckling the dam. Interestingly, a survey of 112 farms in Ontario found 37% of calves showed FTPI, with no difference between heifers and bull calves (Trotz-Williams et al., 2008). While there is a need for an updated comparison of FTPI between male and female calves, these data suggest that colostrum provision remains an industry challenge for both sexes.

Using a serum total protein (STP) cutoff value of 5.5 g/dL (Tyler et al., 1996), researchers have reported between 6% (Pempek et al., 2017) and 43% (Wilson et al., 2000) of calves arriving at a veal facility had FTPI. While this cutoff has good sensitivity and specificity for calves on dairy farms, Renaud et al. (2018b) recently validated the use of STP as an indicator of FTPI in veal calves using a gold standard of 1,000 mg/dL of IgG measured by radial immunodiffusion. This study identified an optimal cut-point of 5.1 g/dL with a corresponding specificity of 84% and sensitivity of 90% for FTPI. Thus, previous research likely overestimated the proportion of calves receiving inadequate colostrum. In their validation study, Renaud et al. (2018b) found 21% of 140 veal calves arrived with FTPI. It is possible that some of the variation in prevalence measured upon arrival relates to a difference in age at the time of sampling, as the concentration of immunoglobulins declines and is not highly correlated with passive immunity transfer after 9 d (Wilm et al., 2018). Another possible reason for the large variation is that dehydration can cause a relative increase in STP, and veal calves sometimes undergo long distance transportation without access to milk or water. However, studies have recently shown STP levels of calves were comparable before and after transportation of up to 12 hours (Fisher et al., 2014; Chibisa et al., 2018). It is also possible that the more recent report showing lower prevalence of FTPI indicates improvement of colostrum management in recent years (Pempek et al., 2017).

While the importance of early colostrum provision has been well studied, researchers have increasingly been investigating the role of milk quality and quantity provided to calves. Previously, feeding milk at 10% of body weight (BW) daily was recommended to encourage early weaning onto solid feed, but calves fed 20% of BW perform less behaviour indicative of hunger, and have greater growth (for a comprehensive review see Khan et al., 2011). Despite the benefits of providing a higher quantity of milk to calves, most dairy farms in a recent survey in Quebec still practiced restricted milk feeding (Vasseur et al., 2010). The quality of milk is also important, as feeding unpasteurized milk to calves results in reduced growth and increased mortality (Godden et al., 2005). In the study by Wilson et al. (2000), milk provision to male calves on dairy farms was likely inadequate as 21.4% had little or no fat reserves upon arrival at a veal facility. More recent research also showed that calves with low body weight upon arrival had lower growth (Renaud et al., 2018d) and higher mortality (Winder et al., 2016) compared to heavier calves. One Canadian survey found 83% of farmers fed the same or more milk to male calves compared to female calves (Renaud et al., 2017). The same survey found farms that had euthanized at least 1 male calf at birth had lower odds of feeding the same or more milk to male calves, suggesting feeding low amounts of milk may be related to a perceived lower valuation of male calves. Further work is required to improve milk-feeding practices for male dairy calves.

Suitable housing on the dairy farm can also contribute to calf health. A recent Canadian survey found 87.9% of farms housed unweaned calves individually – slightly more than the 67.9% reported in the USA (Vasseur et al., 2010). The merit of using group vs. individual housing for calves is controversial as calves in large groups may have increased morbidity (Svensson et al., 2003), but housing calves in smaller groups can increase weight gain (De Paula Vieira et al., 2010), and social contact at a young age can improve the ability of calves to learn new tasks (Meagher et al., 2015). Some housing systems – such as housing calves in crates or tied to a wall in front of the dam's tie stall – reduce both the health and welfare of calves (Vasseur et al., 2010). Pair or small-group housing may realize the benefits of both systems (Whalin et al., 2018).

Ventilation is another important aspect of calf housing on dairy farms, as high ammonia levels and the presence of drafts are risk factors for respiratory disease (Lundborg et al., 2005). While providing calves with clean bedding seems like an obvious way to improve health, bedding cleanliness was not associated with enteric or respiratory disease in a study by Lundborg et al. (2005). In another study, however, calves provided with deep bedding that allowed greater ability to nestle showed a reduction in respiratory disease (Lago et al., 2006). Moreover, calves prefer clean, dry, and soft bedding material (Camiloti et al., 2012; Sutherland et al., 2013). Weather and season also affect environmental management, as calves had higher odds of developing diarrhea if they were born in the summer, and were more likely to develop respiratory disease in the fall and winter (Svensson et al., 2003; Windeyer et al., 2014). There have been no differences documented in the cleanliness or air quality for male *versus* female calves, and it is unclear if this would influence subsequent male calf health. In summary, providing social contact in small groups, good ventilation, and cleanliness in calf housing plays an immediate and possibly long-term role in calf health and welfare.

1.2.2 At the Calf Farm

Calf rearing facilities vary widely in their feeding and housing strategies and these differences can influence calf health and welfare (Bokkers and Koene, 2001). As a disease-prevention strategy, most veal facilities use individual pens or calf separators for the first 6-8 wk to minimize pathogen transfer (Brscic et al., 2012). Nonetheless, high rates of morbidity (Walker, 2012; Pardon et al., 2015), and mortality (Bähler et al., 2012; Renaud et al., 2018c) have been reported. Investigating disease risk factors and prevention strategies has been a focus for welfare research due to the obvious health and economic implications, but some indicators of negative affective state have also been evaluated including oral stereotypic behaviour (Webb et al., 2013) and pain management practices for procedures like dehorning (Duffield et al., 2010; Shivley et al., 2019). This section will review the relevant literature on welfare related to male dairy calf production, focusing on health.

Respiratory and gastrointestinal infectious diseases are the most prevalent problems affecting young dairy calves (Waltner-Toews et al., 1986a; Svensson et al., 2003). Bovine respiratory disease (BRD) and diarrhea occur mostly in the first month of life (Pardon et al., 2012a). In Belgium, a large prospective cohort study followed veal calves throughout the feeding period and found 14.8%, 5.3%, 1.5% and 1.6% of calves were treated for BRD, diarrhea, arthritis and otitis, respectively (Pardon et al., 2013). In a second study, the same research group reported 40% of veal calves were treated for BRD and 15% were treated for diarrhea in the first 18 d on feed (Pardon et al., 2015). In the USA, a cross-sectional survey of calf ranches reported 9% of calves were treated for BRD and 18% for diarrhea (Walker et al., 2012). On post-mortem evaluation of calves from 174 farms in the Netherlands, France, and Italy, “13.9% and 7.7% of lungs showed mild to moderate and severe signs of pneumonia, respectively, and 21.4% of the inspected lungs had pleuritis” (Brscic et al., 2012). Furthermore, gastrointestinal disorders related to poor rumen development have been found in 60.4% of calves, and abomasal lesions were found in 74.1% of calves on post-mortem evaluation (Brscic et al., 2011). The high prevalence of disease has led to frequent use of antimicrobials in veal production and is concerning for both calf welfare and human health due to increasing antimicrobial resistance (Pardon et al., 2012b).

Evaluating risk factors for respiratory disease in veal calves is difficult in part because of a lack of a consistent diagnostic criteria for BRD (Buczinski et al., 2015). However, Brscic et al. (2012) found that higher rates of BRD were associated with lower average body weight of calves at arrival, housing a higher number of calves per pen, and using slatted or straw-bedded flooring. In beef feedlots, co-mingling of calves, increasing distance shipped, and light weight upon arrival have been associated with higher BRD incidence, but the multifactorial nature of the disease has made it difficult to determine the key factors, and many different combinations of factors are likely sufficient to cause disease (Sanderson et al., 2008; Koch et al., 2009). Windeyer et al. (2014) found heifer calves were more likely to be treated for BRD in the first 3 months if they came from herds with a high incidence of BRD or that used manual control of temperature in pre-weaning housing. Furthermore, calves were also more likely to be treated if they showed FTPI, had their navel dipped at birth, or experienced other disease within 2 wk after birth (Windeyer et al., 2014). Studies report an inconsistent effect of season, with lower odds of hampered respiration in winter reported by Brscic et al. (2012) and higher odds of BRD treatment in winter reported by Windeyer et al. (2014). The discrepancy may relate to regional differences or different definitions of respiratory disease. The important risk factors for respiratory disease in veal calves remain controversial, but these studies emphasize the importance of herd-level management of calf environment to reduce BRD.

Calf diarrhea peaks in the first 3 wk after arrival at veal facilities (Pardon et al., 2012a), but there has been little work investigating specific risk factors for the disease associated with management at the calf facility (Santman-Berends et al., 2018). In dairy heifer calves, diarrhea is frequently associated with colostrum management (Svensson et al., 2003) and milk feeding strategy (Godden et al., 2005). A study in New Zealand found that four factors – housing calves indoors, vaccinating cows against enteropathogens, using straw bedding, and having female caretakers for young calves – were associated with reduced odds of liquid feces (Al Mawly et al., 2015). Pathogens for calf diarrhea are considered ubiquitous, and include Escherichia coli, rota- and coronavirus, and Cryptosporidium parvum (Meganck et al., 2015), and their presence alone is likely insufficient to cause disease. Further investigation into feeding and management strategies at calf grower facilities may help elucidate practices that contribute to diarrhea.

Given the relatively high levels of disease in male dairy calves, it is unsurprising that recent studies found between 3.6% (Bähler et al., 2012) and 9.6% (Renaud et al., 2018c) mortality over the feeding period. Most calf mortality occurs during the first 21 d after arrival at veal farms (Pardon et al., 2012a; Winder et al., 2016). Canadian researchers have identified weight as an important factor influencing mortality, as calves that are lighter weight upon arrival had higher odds of mortality in the first 21 d (Winder et al., 2016; Renaud et al., 2018a). Bähler et al. (2012) found calves treated at least once with antimicrobials, that were male, and had insufficient wind deflection in winter (less than three sides of the barn were closed) were more likely to die or be prematurely slaughtered. Further evidence supports that environmental conditions play a role in calf mortality as calves arriving in winter were at increased risk of early mortality in some studies (Winder et al., 2016; Santman-Berends et al., 2018). A retrospective study in the Netherlands identified group-level factors at the veal farm that were associated with increased mortality; these included country of origin, lack of an “all-in/all-out” system, and practicing restricted feeding. A recent case-control study in Canada found lightweight calves with navel disease and severe dehydration had increased odds of mortality within 21 d after arrival (Renaud et al., 2018a). The calf purchasing strategy was also important, with calves supplied through drovers having lower mortality compared to calves derived locally or from an auction. These studies suggest potential calf and herd-level intervention strategies that could be used to improve calf mortality.

1.2.3 Other Welfare Concerns

Beyond health, growth, and other indicators of biological functioning, the welfare of male dairy calves has been questioned by the public. Since Ruth Harrsion described the unnaturalness of veal calf crates (Harrison, 1964), many changes have occurred in the industry. Mandatory group housing for veal calves in the European Union was legislated in the 1990s (Brscic et al., 2012), and in 2008 California passed legislation requiring veal calves to be housed “in ways that allow these animals to lie down, stand up, fully extend their limbs, and turn around freely” (California Legislative Information, 2009). However, individual partitions are still used in the first 6 to 8 wk in the EU and individual housing is common in other parts of the world (Walker et al., 2012). Abnormal oral behaviours like tongue rolling and cross-sucking in veal calves have been of particular concern, as they are thought to reflect behavioural deprivation (Passillé, 2001). Oral behaviours have also been associated with smaller pen and group sizes, and feeding less forage (Leruste et al., 2014), but oral behaviours may help calves cope with stress

(Wiepkema et al., 1987; Webb et al., 2013). Furthermore, although minimum hemoglobin levels are monitored in some countries, some veal calves that are maintained on a milk-based diet likely experience some level of anemia in modern production systems (Marcato et al., 2018).

The use of anesthesia and analgesia for dehorning (Duffield et al., 2010) and castration (reviewed by Coetzee, 2011) are also important for the welfare of male dairy calves. A recent survey found that few dairy operations reported using pain control when dehorning or castrating male calves (Shivley et al., 2019). In Canada, pain control is required by the National Farm Animal Care Code for Veal Cattle (National Farm Animal Care Council, 2017) and Dairy Cattle (National Farm Animal Care Council, 2009), but is not a requirement for beef cattle (National Farm Animal Care Council, 2013). In the EU, most cattle dehorning methods require the use of pain medication, but in a cross sectional survey of EU Member states, for disbudding, only 27.6%, and for dehorning only 43.4% of farms used pain mitigation (Cozzi et al.). While there is little debate on the aversiveness of dehorning and castration, many producers continue to practice these procedures without pain control.

1.2.4 Transportation

Long distance transportation of young male dairy calves has been documented worldwide and can affect calf health (Knowles, 1999; Cave et al., 2005; González et al., 2012b). Dehydration, weight loss, and mobilization of body reserves as identified by increased serum glucose and cortisol levels were documented in early studies on calf transportation (Kent and Ewbank, 1986; Knowles et al., 1997). More recently, Fisher et al. (2014) found calves transported for 12 hours had increased levels of creatine kinase and more lying behaviour compared to calves that remained on their home farm. Furthermore, feed was withdrawn for 30 h in both treatment groups, and calves lost 6% of their body weight and blood glucose levels declined.

A survey of cattle transportation found calves had a higher risk of becoming compromised or dying during transportation, compared to other categories of cattle (González et al., 2012b). This finding was influenced by two loads of approximately 155 dairy calves “with 2 fatalities each plus 5 and 3 non-ambulatory animals in each load”. In Australia, higher mortality rates observed in bob veal calves arriving at a slaughter facility were correlated to a longer distance transported (Cave et al., 2005). Beyond these studies, little is known about the health of male dairy calves before and after transportation, and no studies have related pre-transport conditions to subsequent disease risk. Determining the relationships between calf condition before and after transportation may help develop more specific criteria for fitness for transportation of young dairy calves.

Calf age is considered important for good transportation outcomes and has become a common criterion for deciding whether to transport calves (Knowles, 1995). New Zealand and the EU require that calves undergoing transportation are a minimum of 4 and 14 d, respectively (European Union, 2005; National Animal Welfare Advisory Committee, 2018). In Canada, as of February 2020, transport must be limited to 12 h for calves too young to be fed exclusively hay and grain. Furthermore, in all these regions calves must meet some health criteria including having a dry navel. Canada’s Code of Practice for care of dairy animals does not have specific age or health requirements but recommends to “only load calves for transport if they are healthy and vigorous” (NFACC, 2009). While these provisions demonstrate efforts to ensure calves are fit to be transported, further work is required to improve this practice.

1.2.5 Auctions

Cattle sold through auction markets are at risk for experiencing poor health and welfare outcomes, but until recently little was known about the prevalence of health abnormalities at these facilities. A recent study on cull dairy cows found that some are transported and sold at auction markets in unfit conditions as defined by transportation regulations or industry standards (Moorman et al., 2018). Notably, 40% of cows were thin (BCS ≤2), 70% were suffering from lameness and 27% had hock injuries. Other insights on the condition of cattle at auction were provided by researchers attempting to develop syndromic surveillance. Although breed is not reported, and they could not verify individual animals' identification, they gathered almost 30,000 observations and found 2% of cattle showed evidence of respiratory tract disease, and 0.8% and 0.3% had a low BCS and abnormal ambulation or posture, respectively (Van Metre et al., 2009). Similarly, a pilot study of auctions in Alberta found between 0 and 1.3% of cattle were compromised based on mobility, respiratory signs, BCS or heavy lactation (Heuston et al. 2017). Marquou et al. (2019) evaluated dairy calves at five auction markets in Quebec and found 43% of calves had at least one identifiable health abnormality, most commonly navel disease. Further investigation across regions should be undertaken to determine why such a large variation in cattle condition has been observed, and identify factors associated with better outcomes such as cattle breed, regulatory environment, cultural practices, or economic conditions.

Even for cattle marketed in excellent condition, auction markets are thought to cause fear and distress (Gregory, 2008). This is largely because commercial auctions require multiple animal handling events that are considered the most stressful part of transportation (Kent and Ewbank, 1986; Pettiford et al., 2008). Furthermore, González et al. (2012a) found cattle sold through auctions spent increased time in transit compared to cattle sold directly to a buyer. However, when investigating marketing avenues for lambs in the UK, Murray et al. (2000) found that while auction markets did involve extra handling, direct sales from farm to abattoir could also involve multiple handling events and extended time in transit. Much of the research on cattle welfare at auction markets is from the field of meat science since bruising and dark-cutting meat are more common from livestock marketed through auction (Jarvis et al., 1996; Weeks et al., 2002). While some inferences can be made from these studies, additional work could help elucidate the affective state of cattle in auction markets and gain a better understanding of their welfare.

With the potential for cattle to be marketed in poor condition, experience fear and distress, and be exposed to multiple pathogens, the role of auction markets should be questioned. Auctions vary from traditional stockyards to online video sales, and cattle can be pre-sorted based on their physical characteristics, or shown as owner lots (Bailey et al., 1991). All auctions typically use a competitive, ascending-bid technique that may increase the price farmers receive for their cattle (Klemperer, 1999; Delgado et al., 2008). In Canada and likely elsewhere, auctions also allow efficient flow of cattle, as small beef and dairy farms market cattle to a much smaller number of beef slaughter plants and feedlots (Agriculture and Agri-Food Canada, 2019a; b; Statistics Canada, 2019). The reasons producers market cattle through auctions compared to other avenues has not been investigated, but convenience and economics likely play important roles.

1.3 Research Aims

The aim of this research was to describe the condition of male dairy calves at their dairy farm of origin and determine which characteristics were associated with: (a) price at an auction market, (b) health deterioration immediately after transportation, and (c) morbidity and mortality at calf grower operations. I hypothesized that some calves would be sold and transported with health abnormalities, that would contribute to lower prices and poor health outcomes.

Chapter 2: Early management of male dairy calves influences their health outcomes after long-distance transportation

2.1 Introduction

Successful rearing of male dairy calves is often limited by disease and mortality. One recent study reported that 25% of veal calves developed at least one disease during their lifetime (Pardon et al., 2012a), and a second found that 15% and 61% developed diarrhea and bovine respiratory disease (**BRD**), respectively (Pardon et al., 2015). A high prevalence of respiratory disease was also reported by Brscic et al. (2012) who found evidence of mild to severe pneumonia in 22% and pleuritis in 21% of veal calves on post mortem examination at slaughter. Recent studies have also reported 4 to 10% total mortality throughout the feeding period for veal calves (Pardon et al., 2012a; Lava et al., 2016; Renaud et al., 2018c). Such health challenges have resulted in high levels of antimicrobial use in the male calf industry (Pardon et al., 2012b; Santman-Berends et al., 2018), that is concerning due to the emergence of antimicrobial resistance in human and animal pathogens. Thus, disease and mortality in male calves remain important topics for research for animal welfare and calf production.

The care of male calves at the dairy farm of origin involves many risk factors that may influence disease including: the quality and quantity of colostrum provided, the type and cleanliness of housing, and exposure to adverse events such as dystocia (Brscic et al., 2011, 2012; Lava et al., 2016; Winder et al., 2016). Additionally, calves that are marketed at a young age may be vulnerable to health challenges, as low body weight has been associated with higher mortality in calves arriving at veal facilities (Pardon et al., 2015; Renaud et al., 2017).

Researchers have suggested that better management at the dairy farm and improved marketing practices could increase calf health and welfare (Shivley et al., 2019).

Long-distance transportation of young calves has been associated with dehydration, weight loss, and mobilization of body reserves as identified by increased serum glucose (Kent and Ewbank, 1986; Knowles et al., 1997). Mortality of neonatal veal calves arriving at a slaughter facility is correlated to distance transported (Cave et al., 2005). Additionally, surveys on over 6,000 loads of cattle in North America found calves had a higher risk of becoming compromised (dead or non-ambulatory) compared to other classes of cattle (González et al., 2012b). This finding was largely influenced by 2 loads of male dairy calves in which 4% of calves became compromised, compared to 0.045% of cattle in the total study population. While these studies suggest long distance transport negatively affects calf health, there has been little observational investigation evaluating the effect of calf condition before transportation on their health outcomes. Furthermore, while Gonzales et al. (2012b) documented young dairy calves can be transported over 1,300 km in North America, the duration and distance of calf transport has received little additional attention.

Because calf age and health are considered important for good transportation outcomes (Knowles, 1995), many countries have specific requirements for calf condition before transportation. For example, New Zealand (Ministry for Primary Industries, 2018) and the European Union (European Union, 2005) require calves to have healthy navels, and be a minimum age of 4 and 14 d before transportation, respectively. Recently, Canada introduced regulations to reduce the transportation of unweaned calves from 18 to 12 hours, prohibit transport of calves with unhealed navels, and require that calves less than 9 days be moved directly between farms, not to auctions or assembly yards. However, there has been little specific research to inform these policies, and no studies have related pre-transport calf health to subsequent morbidity and mortality.

This prospective single-cohort study had three objectives: (1) to describe the condition and management of male calves at the dairy farm of origin before transportation, (2) to evaluate potential risk factors for poor health outcomes (3) to determine how calf condition before transport influenced morbidity and mortality at calf grower operations.

2.2 Materials and Methods

2.2.1 Study Participants

Dairy farms and calf growers were recruited in September 2017 through veterinary clinics practicing in Western Canada. Inclusion criteria for dairy farms included proximity to the Fraser Valley region of British Columbia, Canada, and selling male dairy calves at least weekly. Of 19 dairy farms approached, 17 agreed to participate. Basic dairy farm management data (herd size, calf housing type, and calf feeding practices) were collected by a short survey. Farms were visited regularly (weekly or biweekly depending on the farm management) and calves were evaluated within 24 h before transportation to either a local auction market or to one of two calf growers. Inclusion criteria for the calf growers (CG) included willingness to participate, and purchase of male dairy calves from British Columbia; two calf growers (CG1, CG2) agreed to participate that were an average of 1,050 km from the dairy farms. A power calculation showed that 870 calves would be required to detect a difference of 10 vs. 5% mortality in calves with vs. without a health abnormality using an α=0.05 and β=0.80. This target sample size was achieved at the dairy farms of origin, but the number of calves available for follow-up was lower due to logistical challenges with confirming transport and arrival dates.

2.2.2 Calf Assessments

From October 1, 2017 to March 31, 2018, 885 calves were assessed by a single veterinarian using a standardized health examination. Calves were marked on the forehead and rump with highly visible livestock paint (Tell Tail Aerosol, FIL Industries, New Zealand) to allow them to be identified after transportation. The health examination was conducted using the Calf Health Scorer App (University of Wisconsin-Madison, Madison, WI), which uses a 4-point scoring system for various health parameters, as described by Renaud et al. (2018b). The sum of ear, eye, nose, cough and temperature scores is the BRD score (McGuirk and Peek, 2014). Each health score was collapsed into a binary variable denoting “normal” and “abnormal” based on biologically relevant values using the criteria in Table 2.1. This was done because of the low frequency of abnormal scores in the sample, and to improve the intra-observer agreement and for ease of interpretation.

Table 2.1. Criteria for converting raw calf health scores from the Calf Health Scorer App into dichotomized scores (0 or 1 for normal or abnormal) for use in regression models and descriptive statistics

Health Score	Normal	Abnormal	Description of Abnormal Clinical Signs
Attitude	≤1	>1	Dull, unwilling or unable to rise
Pyrexia	≤2	>2	Body temperature greater than 39.3 °C
BRD [a]	≤4	>4	The sum of scores related to body temperature, ocular or nasal discharge, and coughing
Fecal	≤1	>1	Feces watery in consistency
Navel	≤1	>1	Navel swollen and painful with or without malodourous discharge

[a] Bovine Respiratory Disease

Along with health assessments, a jugular blood sample was collected from all calves; 567 of these animals were confirmed (based on birthday or communication with farmers during weekly visits) to be aged 1 to 9 d (Wilm et al., 2018) and were therefore included in the analysis. Two of the 17 farms had fewer than 5 calves with eligible blood tests and were not included in the calculation of median and **IQR** (interquartile range) for farms. The pre-transport health assessment was conducted on the same day as blood sampling for calves transported at ≤ 9 d; otherwise the health assessment was conducted at a subsequent visit. Serum total protein (**STP**) was measured with an optical refractometer (Reichert Vet 360, Reichert, Inc., Depew, NY) and failure of transfer of passive immunity (**FTPI**) was defined as < 5.2 g of STP per dL (Calloway et al., 2002). Calf age was calculated using the birthday recorded in each farm's records and was not included in analysis if the date was missing or appeared inaccurate. As an estimation of calf weight, a circumferential measurement ("heart girth"; **HG**) was taken of each calf's chest just caudal to the elbow joint using a soft measuring tape (The Coburn Company, Inc., Whitewater, WI, USA) and converted to weight using a formula validated by Heinrichs et al. (2007) and Bond et al. (2015).

Subsequently, the same veterinarian evaluated 161 of the calves 1 to 5 h after they were off-loaded at CG1 or CG2 on 8 separate occasions between November 1, 2017, and March 31, 2018. Calves destined for CG1 arrived at the farm in the evening and remained in the transport trailer overnight before being off-loaded and evaluated the following morning. CG2 calves typically arrived and were off-loaded and evaluated in the morning. This second evaluation included the standardized calf health examination and a jugular blood sample for a second measurement of STP. Calf transport times could not be verified individually due to multiple farm pickups, but the trip duration generally ranged from 12 to 24 hours. The transportation protocol practiced by CG1 included provision of oral meloxicam suspension (Solvet, Canada) at the mid-point of the trip, but administration of the medication could not be verified for calves individually. Protocols for animal assessments and sampling were approved by the University of British Columbia Animal Care Committee (application A16–0336-001).

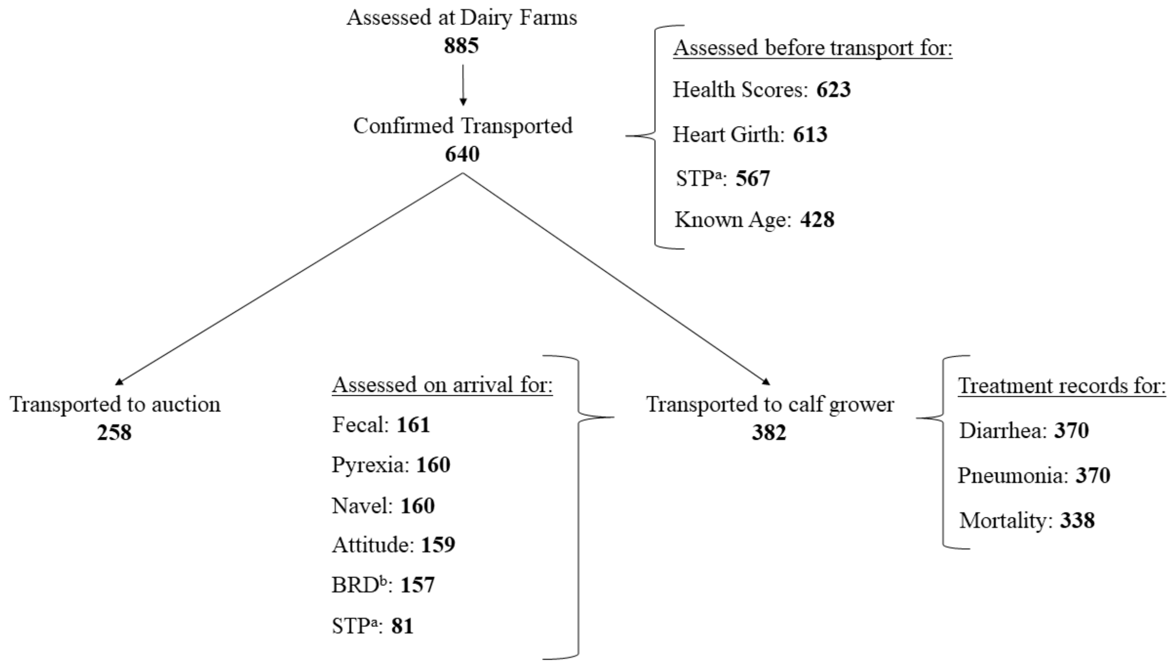
2.2.3 Morbidity and Mortality

During their first 2 weeks at the calf growers, calf health was assessed daily by farm staff, and any disease treatments or deaths were recorded. Diarrhea was defined as watery fecal consistency and BRD was recorded when an increased rate, sound or effort of respiration was identified in combination with pyrexia and one or more additional signs (coughing, nasal discharge, depression, decreased appetite, or rough hair coat). Producers agreed with the case definitions when reviewed with the veterinarian, but farm treatment protocols were not altered for the study. Calves were treated primarily for diarrhea or BRD; other diseases uncommonly identified by the producers included bloat, otitis, and navel disease. Treatments for diarrhea included supportive therapy (orally administered activated charcoal) and antimicrobials for calves with severe symptoms. BRD treatment consisted of antimicrobial therapy with or without non-steroidal anti-inflammatories. At CG1, calves were treated by either one experienced employee or the farm owner. On CG2, all disease diagnoses and treatments were completed by one farm owner.

2.2.4 Statistical Analyses

Due to logistical constraints in following calves throughout the study, each analysis used a different subset of calves (Figure 2.1).

Figure 2.1. Flow chart showing the number of calves for the different statistical analyses used in this study. The number of calves represented at each level is in boldface.



a: Serum total protein
b: Bovine respiratory disease

2.2.4.1 Pre-transport Descriptive Data

Only calves with complete health scores (n=623) that were confirmed to be transported to the calf grower or auction were included to ensure that evaluations reflected calf condition within 24h of transport. Microsoft Excel was used to tabulate descriptive data (Microsoft Corporation, Redmond, Washington, USA). Median and mean measures of central tendency are reported depending on the data distribution. The proportion of calves that showed health deterioration was evaluated using Rstudio version 1.2.1335 (Rstudio Team, 2018); all other data analysis was performed using SAS University Edition (SAS Institute Inc., Cary, NC).

To verify intra-observer agreement for health measures in the standardized exam, 25 calves at the University of British Columbia's Dairy Education and Research Center were assessed twice on one day, approximately 3 h apart. Weighted (for measures with multiple levels) and unweighted (for binary measures) kappa coefficients were used to determine agreement. Cicchetti-Allison (linear) weight type was used for the weighted kappa calculation (Cicchetti-Allison, 1971). Intra-observer agreement for HG was calculated by a concordance correlation for 106 calves that were assessed within 1 hour before transportation (as part of this study) and again approximately 3 hours later at an auction market.

2.2.4.2 Health Deterioration After Transport

For evaluating changes in health score immediately after transportation, up to 161 calf measurements were available. The correlation between STP measured before vs. after transportation was based on 81 calves because 80 calves were missing a measurement of STP or were > 9 d at the time of the second sample. Since calf health measures were paired before and after transport and clustered by farm, a McNemar's test with Durkalski's adjustment was used to evaluate changes (Durkalski et al., 2003), using the "clust.bin.pair" package of R package version 0.1.2 (Gopstein, 2018). A paired t-test and Pearson correlation (r) were used to compare STP levels before and after transportation (Proc Univariate). The assumption of normality was confirmed with data visualization and a Shapiro-Wilk test for normality.

For each health category (attitude, pyrexia, BRD, fecal, navel), calves were scored 1 if they had deteriorated after transport and 0 if condition was unchanged or improved. Logistic mixed-effect models were then used to test the effect of age, HG and FTPI on heath deterioration, with dairy farm of origin included as a random effect. Model building was completed using Proc glimmix with a binary distribution and logit link function. Pearson correlations between explanatory variables were calculated to assess collinearity, with none showing a coefficient > 0.6. Initially, univariable regression models were used to determine if age, HG or FTPI were associated with health deterioration (Table 2.2). Factors liberally associated in univariable modelling ($P < 0.2$) were offered to the multivariable model using backwards elimination.

2.2.4.3 Morbidity and Mortality

A similar model-building procedure was used for morbidity and mortality at the calf growers using Proc glimmix. Three models were created where calves were scored 1 if they were treated for diarrhea in the first 2 weeks (model 1), treated for BRD in the first 2 weeks (model 2), or died during these 2 weeks (model 3). In each model, calves were scored 0 if they remained untreated in the 2 weeks (models 1 and 2) or survived the 2 weeks (model 3). Logistic mixed-effect models were used to test for associations between these outcomes and age, HG, FTPI, and the dichotomized health scores taken on the dairy farm of origin. Dairy farm within calf grower was considered a random effect. Six calves were confirmed arrived but were lost to follow-up and did not have treatment or mortality records. The 6 calves that died before the end of week 2 without being treated for diarrhea or BRD were not included in morbidity regression analysis. A further 38 calves that were lost to follow-up and could not be confirmed alive after 2 weeks were not included in mortality analysis.

2.3 Results

For the 25 calves assessed at one farm 3 h apart using the 4-point health scale (0 to 3), the percent intra-observer agreement ranged from 36 to 100%. With health scores converted to dichotomized scores (0 or 1 for normal or abnormal), percent agreement increased and ranged from 88 to 100%. For HG measured for 106 calves 3 h apart, the concordance correlation coefficient for intra-observer agreement was 0.95.

Table 2.2

Intra-observer agreement between health scores of 25 dairy calves assessed 3 h apart using raw health scores (0 to 4, or 1 to 6 for the combined BRD score) and dichotomized scores (0 or 1)

	Raw Scores		Dichotomized Score	
Health Score	Weighted or Unweighted Kappa [b]	Percent agreement	Unweighted Kappa	Percent agreement
Attitude	0.78*	96%	1.00	100%
Pyrexia	0.48	60%	0.46	92%
BRD [a]	0.48	36%	0.59	88%
Fecal	0.54	68%	0.86	96%
Navel	1.00 *	100%	1.00	100%

[a] BRD: Bovine Respiratory Disease

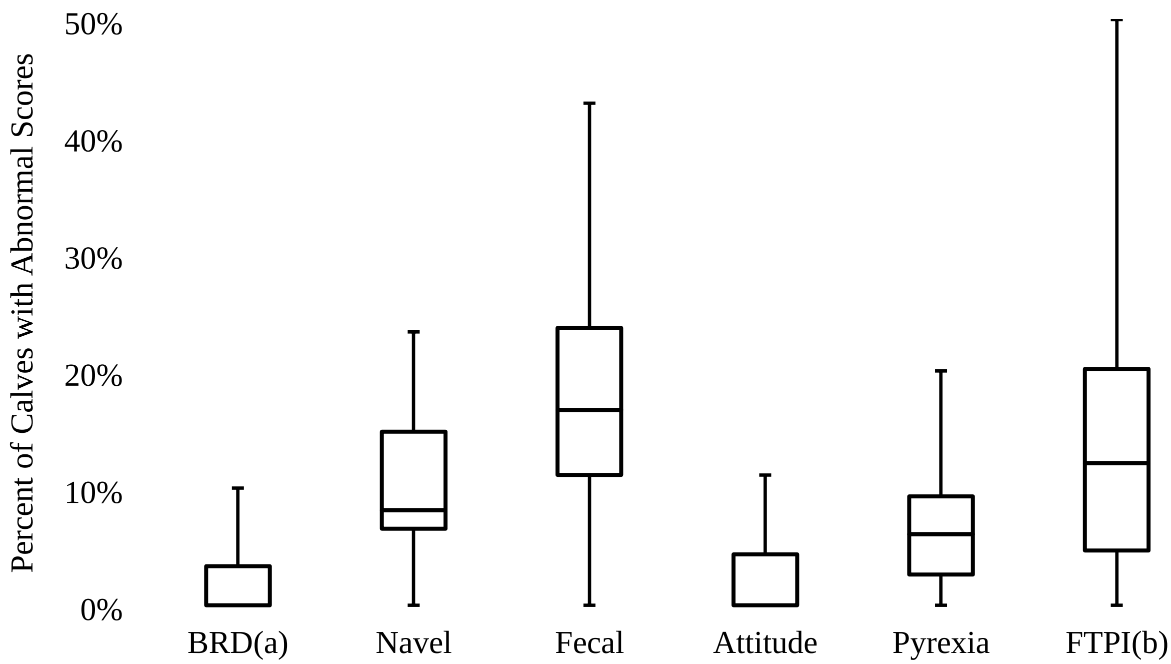
[b] An unweighted kappa was used to calculate values marked with an asterisk (*) as only 2 levels of health scores were observed, whereas values in this column without an asterisk used weighted kappa.

2.3.1 Descriptive Data

Expressed as median and interquartile range (**IQR**), the dairy farms had milking herds of 290 cows (205 to 401) and transported 30 (21 to 49) calves during the study. Calves received a median (range) of 6 (4 to 8) L of milk per day provided as two daily meals. Three farms did not feed calves on the day they were transported. Farms fed calves unpasteurized waste milk (9 farms), milk replacer (6), pasteurized waste milk (1), or both unpasteurized waste milk and milk replacer (1). Male calves were raised in a different area or type of housing than female calves in 12 farms, while 5 farms used similar housing for both sexes. Individual hutches were used for male calves on 10 farms, while 7 used a group pen or a mix of individual and group or pair housing.

The prevalence of disease and disease symptoms in male calves varied widely among the different dairy farms (Figure 2.2). The percentage of calves with fecal score indicating diarrhea ranged from 0 to 43% with a median (IQR) of 17 (11 to 24) %. FTPI had a median (IQR) of 12% (4-19%), with two farms showing no cases of FTPI. At least 1 health abnormality was identified in 37% of calves in their pre-transportation assessment, but this ranged from 15% on one farm to 67% on another. However, the variation did not appear related to the farm-level variables such as type of milk fed, herd size, or housing type.

Figure 2.2 Box and Whisker plot of the prevalence of disease, disease symptoms (n=623) and failure of transfer of passive immunity (n=567) in male dairy calves assessed ≤ 24 h before transportation from 17 BC dairy farms. Boxes show medians with upper and lower quartiles; whiskers indicate range. (a) Bovine Respiratory Disease (b) Failure of Transfer of Passive Immunity, defined as Serum Total Protein < 5.2 g/dL.



Of the 640 calves confirmed to be transported, 258 were transported to an auction market and 382 to one of two calf growers. The median (IQR) age of calves at transportation for the 428 of known age was 5 (3 to 7) d, ranging from 1 to 54 d (Figure 2.3). Mean ± SD heart girth of calves was 82 ± 4 cm, which correlates to 44 kg BW (Heinrichs et al., 1992), with calves ranging from 67 cm (~27 kg) to 98 cm (~77kg) (Figure 2.4).

Figure 2.3. Ages of 428 male dairy calves at the time they were transported to calf grower operations from 17 dairy farms in British Columbia

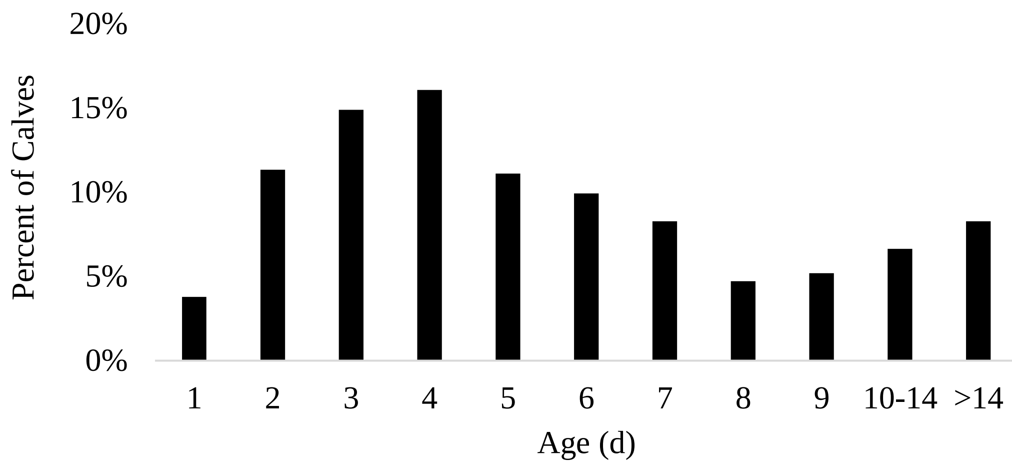
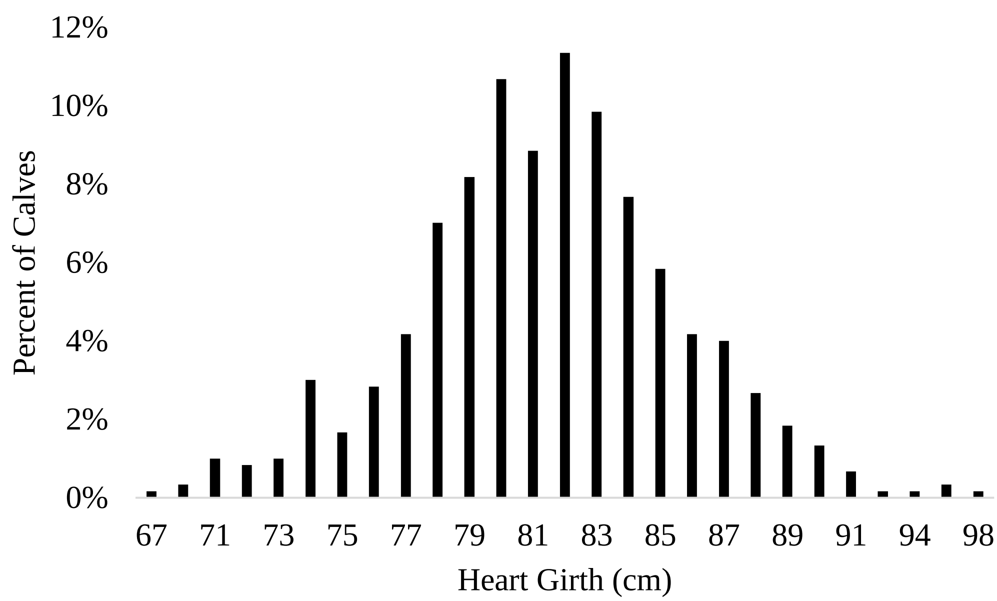


Figure 2.4. Heart girth measurements of 613 male dairy calves at the time they were transported from 17 dairy farms in BC



2.3.2 Health Deterioration After Transport

For the calves assessed just before and after long-distance transportation to a calf grower, a larger proportion had an elevated body temperature after transport and a smaller proportion displayed evidence of diarrhea (Table 2.3). Logistic regression models revealed few associations between calf condition scored at the dairy farm and health deterioration during transport; however, calves with STP < 5.2 g/dL measured at the dairy farm had greater odds of developing a depressed attitude after transport (OR: 11.6; 95% CI: 2.7 to 50.9; P = 0.001). Mean ± SE STP was similar before and after transport at 5.9 ± 0.07 g/dL and 6.0 ± 0.07 g/dL (P = 0.16). Levels before and after transport were highly correlated (r=0.80).

Table 2.3. The percentage of male dairy calves with health abnormalities at the dairy farm and after arriving at the calf grower, with statistical analysis by McNemar test with Durkalski's adjustment

	Location			
Abnormal Health Score	Dairy Farm (%)	Calf Grower (%)	*n*	*P*
Attitude	15.7	17.4	159	0.721
Pyrexia	3.8	8.7	160	0.037
BRD [a]	1.9	2.5	157	0.436
Fecal	18.0	7.5	161	0.028
Navel	9.4	14.3	160	0.095

[a] BRD: Bovine Respiratory Disease

2.3.3 **Morbidity and Mortality**

During the 2 weeks after transportation, disease treatments and deaths were recorded for 376 of the calves including the 161 calves that were assessed upon arrival. During these 2 weeks, 23% were treated for diarrhea, 44% were treated for BRD and 3.9% died. A larger proportion of calves were treated for disease at CG2 compared to CG1 (40% vs. 6% for diarrhea, 78% vs. 9% for BRD), but similar mortality was observed at both locations (3.8% vs. 3.9%). Factors associated with morbidity and mortality in univariable analysis using a cutoff of *P*<0.2 are reported in Table 2.4.

Table 2.4. Univariable analysis of factors (assessed at the dairy farm) associated with diarrhea, bovine respiratory disease, and mortality among male dairy calves in the first 2 weeks after arrival at a calf grower, including variables associated at *P*<0.2.

Health Outcome	**Variable**		**n**	**OR**	**95% CI**	***P***
Diarrhea	FTPI[a]	Fail	50	2.0	1.0 - 4.2	0.067
		Pass	300	Referent		
	HG[b]	Every 1 cm increase	364	0.9	0.8 - 1.0	0.009
	Navel	Abnormal	39	2.2	1.0 - 4.9	0.046
		Normal	329			
	Pyrexia	Abnormal	17	3.5	1.2 - 10.9	0.024
		Normal	350	Referent		
BRD[c]	BRD[c]	Abnormal	7	6.5	0.8 - 52.3	0.080
		Normal	355	Referent		
	HG[b]	Every 1 cm increase	364	1.1	1.0 - 1.2	0.068
Mortality	Attitude	Abnormal	11	11.7	2.7 - 51.4	0.001
		Normal	324	Referent		
	BRD[c]	Abnormal	7	4.3	0.5 - 39.0	0.190
		Normal	323	Referent		
	Fecal	Abnormal	64	3.9	1.3 - 12.1	0.020
		Normal	272	Referent		
	HG[b]	Every 1 cm increase	329	0.9	0.8 - 1.0	0.050

[a] FTPI: Failure of Transfer of Passive Immunity, defined as Serum Total Protein < 5.2 g/dL
[b] HG: Heart Girth circumference (cm)
[c] BRD: Bovine Respiratory Disease

In the final logistic regression model, both smaller HG and abnormal navel score were associated with increased diarrhea treatment in the first 2 weeks (Table 2.5). However, an interaction was found between navel score and HG, such that calves with a small heart girth that had navel disease had increased odds of being treated for diarrhea in the first 2 weeks. In addition, calves with a depressed attitude at the dairy farm had increased odds of dying in the first 2 weeks at the calf grower. No factors measured at the dairy farm were associated with BRD treatment during the 2 weeks after arrival at the calf grower.

Table 2.5. Logistic mixed regression model of associated risk factors for male dairy calves being treated for diarrhea or dying in the first 2 weeks at a calf grower

Outcome	Variable	Estimate	SE	t	*P*	OR	95% CI
Diarrhea	Intercept	5.5	3.5	1.57	0.14	.	.
	Abnormal Navel	23.2	10.6	2.18	0.03	2.8	1.2-6.7
	Normal Navel	Reference	.		.	.	.
	HG[a] (cm)	-0.09	0.04	-2.05	0.04	0.9	0.8-1.0
	HG[a] * Navel interaction						
	HG[a] with Abnormal Navel[b]	-0.3	0.13	-2.09	0.04	0.7	0.5–0.9
	HG[a] with Normal Navel[b]	Reference	.		.	.	.
Mortality	Abnormal Attitude	2.5	0.75	3.29	0.001	11.8	2.7–51.4
	Normal Attitude	Reference		.	.	.	.

[a] Heart Girth (cm)
[b] Based on 1 cm offset from the mean heart girth (81.1 cm)

2.4 Discussion

Of the 640 calves that were assessed before transportation, many had an identifiable health abnormality and the prevalence of these abnormalities varied depending on the dairy farm of origin. Calf disease on dairy heifer farms and veal operations is a considerable challenge, and has been linked to colostrum provision, housing cleanliness, and body weight upon arrival (Windeyer et al., 2014; Lava et al., 2016; Winder et al., 2016). The importance of reducing calf disease has been emphasized because of the negative welfare implications (Hulbert and Moisá, 2016) and to minimize the use of antimicrobials in food animals (Holstege et al., 2018). However, the use of good calf management practices is highly variable among farms (Atkinson et al., 2017; Renaud et al., 2017), so the variability in calf condition seen in our study is not surprising.

Some calves in this study were transported at a very young age and light weight. However, age itself was not a predictor of immediate health deterioration, morbidity or mortality and was not highly correlated with HG in this data set. Our findings do not agree with earlier research which found lower mortality in calves transported at 4 d compared to 1 d (Barnes et al., 1975), and in calves transported under 2 wks old compared to older ages (Staples and Haugse, 1974). In a review of transportation of calves, Knowles (1995) noted that younger calves had higher mortality in the first 4 weeks after transportation. Younger calves have also been found to spend more time lying during transportation, but it is unclear if this is indicative of poor health (Jongman and Butler, 2014). While weight of calves entering veal facilities is an important risk factor for mortality (Winder et al., 2016; Renaud et al., 2018a), the optimal age and weight for transport of dairy calves has not been well established. Further research using a wider range of ages is warranted to determine whether there is an optimal age to transport young calves.

Interpretation of herd-level factors is limited because of the small number of farms in the current study. Similar to our findings, other work has shown that male calves were more likely than female calves to be housed individually (Renaud et al., 2018c), perhaps because farmers wanted to keep male calves healthy before transport. Regarding feeding practices, calves were provided a smaller quantity of milk than is currently recommended, and some were provided unpasteurized waste milk, which has been associated with reduced immunity and productivity (Vasseur et al., 2010; Khan et al., 2011).

Levels of FTPI in this study were comparable to levels seen in some recent studies (Atkinson et al., 2017; Renaud et al., 2018c), but lower than those reported in earlier survey results (Trotz-Williams et al., 2008). This could be due to sampling bias or could reflect improved colostrum management in recent years. In a recent Canadian survey, 91% of farmers reported always feeding colostrum to male calves (Renaud et al., 2017), as is consistent with our observations of FTPI. The variation between farms was notable, however, with 2 farms having no calves with FPTI and others having a very high rate of failure. This finding, together with the observed differences in the environmental and nutritional management, emphasizes previously observed inconsistency in care for male calves on their farm of origin (Shivley et al., 2019).

Of the 161 calves that were assessed before and after transportation, the percentage with diarrhea was lower at the calf grower than at the farm of origin. This may reflect dehydration as calves did not receive milk or water for an estimated 24 to 36 hours before and during transport, and/or the use of oral meloxicam (Todd et al., 2010). Indeed, Chibisa et al. (2018) found better gastrointestinal health when meloxicam was given before long-distance (8.5 h) transportation of Jersey calves. The slight (non-significant) increase in STP after transport might also have been due to dehydration. More calves had pyrexia after transportation; this could reflect an inability of young calves to closely regulate their body temperature during transportation as seen in previous studies (Knowles et al., 1997).

Calf STP levels were similar and highly correlated before and after transport for the 81 calves assessed. This supports the results of Fisher et al. (2014) who compared calves transported up to 12 hours to control calves that remained on their home farm, and Chibisa et al. (2018) who found no effect on STP in Jersey calves that were transported 8.5 h. Serum total protein taken from male dairy calves upon arrival at rearing facilities has been used as an indication of FTPI and has been predictive of respiratory disease and mortality (Windeyer et al., 2014; Pardon et al., 2015). Our results support the growing evidence that STP measured upon arrival at calf rearing facilities can be a useful management tool.

Calves with FTPI were more likely to develop a depressed attitude after transportation. While "depressed attitude" is not a clinical diagnosis, it has been described as a symptom of septicemia, fatigue, and dehydration (Pempek et al., 2017) and may indicate an inability of the calf to cope with external conditions. Our study supports this, as calves with a depressed attitude at the dairy farm had greater odds of dying in the first 2 weeks at calf grower facilities. As reduced immunoglobulin concentration has also been correlated to poor health outcomes in male calves (Pardon et al., 2015), the correlation between FTPI and depressed attitude in this study may have been an early sign of impending disease. Calf "attitude", although not specific to any one disease condition, may be useful for assessing fitness for transport and could be predictive of poor health outcomes.

In this study, calves with swollen navels and small HG were especially likely to be treated for diarrhea. Previous work has identified weight (Brscic et al., 2012; Winder et al., 2016) and navel disease (Renaud et al., 2018a) as important risk factors for disease and mortality in veal calves. Navel disease did not increase the probability of being treated for diarrhea for calves with larger HG, who may have been more resistant to developing illness due to age (Waltner-Toews et al., 1986b) or a higher plane of nutrition (Khan et al., 2011). Other unmeasured factors may also have been important in this finding including poor environmental cleanliness and lack of preventative measures like navel dipping that may have resulted in both poor growth and navel infection.

In the first 2 weeks of this study, 44% of calves were treated for BRD which was comparable to Pardon et al. (2015) who noted 60% cumulative incidence of BRD over the first 18 d. Interestingly, none of the calf conditions measured at the dairy farm of origin was clearly related to BRD outcomes at the calf grower in the multivariable model. In contrast, Pardon et al.

(2015) found immunoglobin levels below 7.5 g/L to be predictive of respiratory disease in the first 18 days at the calf grower. It is possible that environmental and management factors (air quality, nutrition, mingling of animals) had a greater influence on the development of BRD in our study.

In conclusion, in this prospective single-cohort study some calves were transported at a young age and light weight, sometimes displaying disease symptoms that should preclude transport. Calves transported with FTPI, a depressed attitude, or lightweight combined with navel disease were more likely to experience poor health outcomes upon arrival and during the first 2 weeks at calf grower facilities. These findings indicate there is a need to improve the health of male dairy calves before they are transported. Further clarification on the optimum age and weight, and other criteria for transport of calves are necessary to inform policy and protect male dairy calf health and welfare.

Chapter 3: Male dairy calf genetics, health condition, and weight influence price at a commercial auction market

3.1 Introduction

The marketing of cattle in poor health and body condition is a welfare concern. Recent studies have identified cattle suffering from lameness, thin body condition, and respiratory disease at auction markets (Barham and Troxel, 2007; Van Metre et al., 2009; Moorman et al., 2018). For male dairy calves, a recent study conducted at 5 auction markets in Quebec identified that 43% had at least 1 health abnormality (Marquou et al., 2019). This high prevalence of abnormalities is concerning as a recent NAHMS survey in the USA found that 61.2% of dairies sold their male calves through auctions (Shivley et al., 2019).

While calf sales generally make up only a small portion of dairy farm income, price fluctuation likely influences farmers' decisions on how and when to market calves, and perhaps the quality of calf care. Renaud et al. (2017) reported the price paid for calves at auctions in Quebec, Ontario and Nova Scotia and noted variability both within and between years. The authors also found that some regions that typically received lower prices for male calves also reported higher use of euthanasia at birth, although other regional factors might also have influenced this association. Winder et al. (2016) found calves purchased for a lower price were likely in poor condition as they tended to have higher subsequent mortality risk on veal farms. In Quebec auctions, smaller calves with inflamed joints and other unhealthy characteristics were sold for lower prices (Marquou et al., 2019). This suggests some calves are marketed in poor condition despite the higher prices paid for healthy calves.

Further investigation into the prevalence of health abnormalities and the range in calf price at auction markets is needed. The objectives of this study were to provide a description of the health condition and sale price of male dairy calves at a live auction in British Columbia, Canada, and to determine which factors were associated with price.

3.2 Materials and Methods

Calves from dairy farms were observed every week or every second week at a live auction market in British Columbia from October 1, 2017 to March 31, 2018. Calves were delivered in the morning by local dairy farmers or transporters, tagged with a penetrating ear tag for visual identification, and housed in a bedded group pen. Calves did not have access to forage, milk, or water, and had fence-line contact with cull dairy cattle. At the time of sale, calves were most commonly placed in the sale ring alone and a price was determined through live bidding. Occasionally, a group of similar calves would be placed in the ring together and the highest bidder would have the choice to purchase any number of the calves in the ring. If all the calves were not selected, a second round of bidding would follow until all calves in the group were sold. Calves that were sold were moved to a bedded pen with access to a chute system including a ramp where they could be loaded for transportation. If no bid was placed, a price of 0 was recorded and the calf was removed to a separate pen. Price, breed, and sex were recorded for 1661 calves from 18 separate sale dates, with a range of 60 to 131 calves recorded per day. Calf breed was recorded based on phenotypic characteristics and included the dairy breeds of Holstein, Jersey, and Brown Swiss, as well as calves with mixed dairy and beef (Angus or Belgian Blue) genetics.

Since it was not possible to assess the health of all calves, 388 calves (383 bulls, 5 heifers) were assessed including 264 that were selected randomly (all calves with either odd- or even-numbered ear tags as decided on each assessment day by tossing a coin), and 124 that were assessed because they were part of a larger study on calf transportation that followed a sample of calves from farm to their final destination at calf grower facilities. The assessment was done within 2 h before the sale and included a standardized health examination recorded using the Calf Health Scorer App (University of Wisconsin-Madison, Madison, WI), which uses a 4-point system as previously described by Renaud et al. (2018a). At the request of auction management, the assessment did not include rectal temperature. Ear score was not recorded because the recent application of a penetrating ear tag caused some calves to display head shaking and ear drooping. Since calves were housed in a group and a rectal exam could not be performed, an accurate fecal score could not be obtained. Therefore, only attitude, ocular or nasal discharge, cough, navel and joint scores were analyzed. Along with the health assessment, calf weight was estimated using a heart girth circumference (**HG**) measured just caudal to the elbow joint using a soft measuring tape (The Coburn Company, Inc., Whitewater, WI, USA) (Heinrichs et al., 2007; Bond et al., 2015). Protocols for animal assessments and sampling were approved by the University of British Columbia Animal Care Committee (application A16–0336-001).

Descriptive statistics were calculated using Microsoft Excel (Microsoft Corporation, Redmond, Washington, USA). Health scores were collapsed into a dichotomous variable denoting “normal” and “abnormal” (Table 2.1). Intra-observer agreement was calculated as described in Chapter 2. Due to market variation over time, a standardized price (deviation from median price on the day of sale) was calculated by methods following Marquou et al. (2019). Median price was calculated for each day based on all calves sold at the auction market that day. Standardized price was compared between male and females calves of different breeds for the 1661 calves.

Individual calf health assessment data were evaluated for completeness of HG and health scores, and this resulted in 360 calf assessments available for regression analysis. Of the 360, there were only 3 Brown Swiss, 4 Jersey, and 5 heifer calves, so they were removed from regression analysis, leaving 348 calves. The effects of beef vs Holstein breed, health scores and HG on standardized price were analyzed using a linear regression model (Proc Mixed) following methods in Dohoo et al. (2003). Variables were assessed individually for association with standardized price, and associated factors ($P < 0.2$) were tested in the multivariable model. Manual backwards elimination was used to remove variables with a non-significant association ($P > 0.05$). Breed was retained in the model based on a previous work indicating a strong association with price (Marquou et al., 2019), and was significant once navel score was removed. The resulting model which included HG, attitude, and breed had a lower AIC compared to HG and attitude alone. Collinearity was assessed between variables in the final model using a Spearman rank correlation with a cutoff value of > 0.6 and variance inflation factors with a cutoff of ≥ 5. No collinearity between variables was observed. All pair-wise interactions were evaluated in the final model and none was significant. The model was evaluated visually for normality using a plot of residuals and predicted outcomes. All model building was conducted in SAS University Edition.

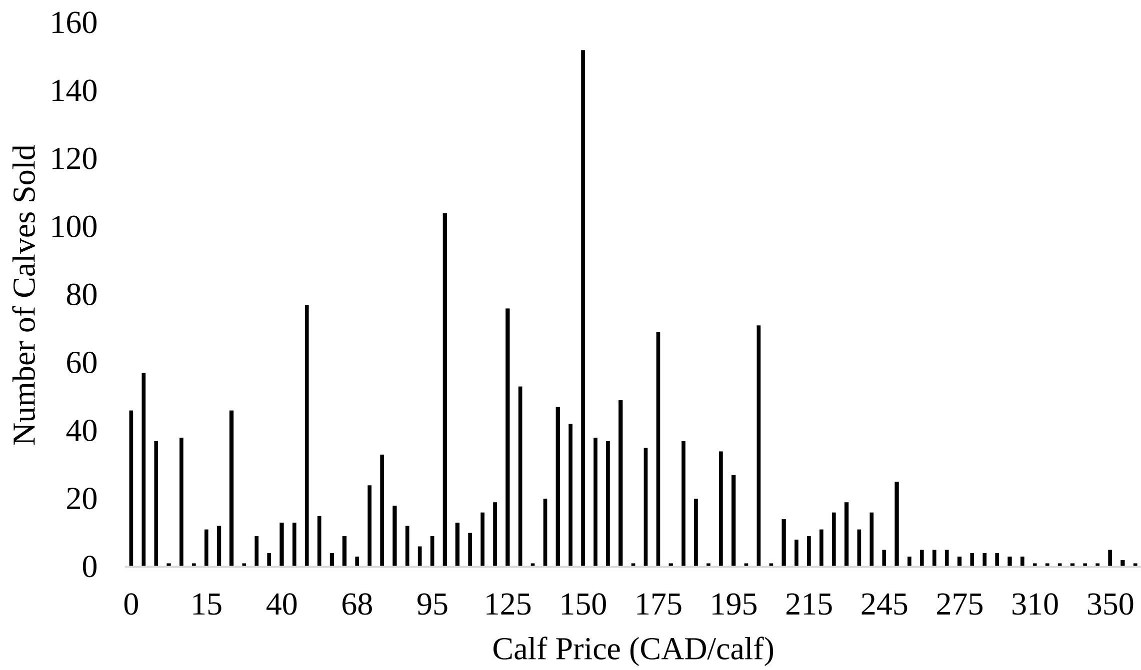
For comparative data from other regions, information about calf prices was collected for the year 2018 from auction markets in Nova Scotia (Altantic Stockyards Limited, 2019) and Quebec (Les Producteurs de bovins du Québec, 2019) using each organization's publicly accessible website. The mean weekly price for "average" versus "good" bob calves was collected from the Atlantic Stockyards. The mean weekly prices for Holstein "divers" (low-quality) calves compared to "good" or "average" calves were collected from Les Producteurs de Bovins du

Quebec. Weighted mean weekly price for each calf category was calculated based on the mean weekly price weighted by the number of calves sold that week.

3.3 Results

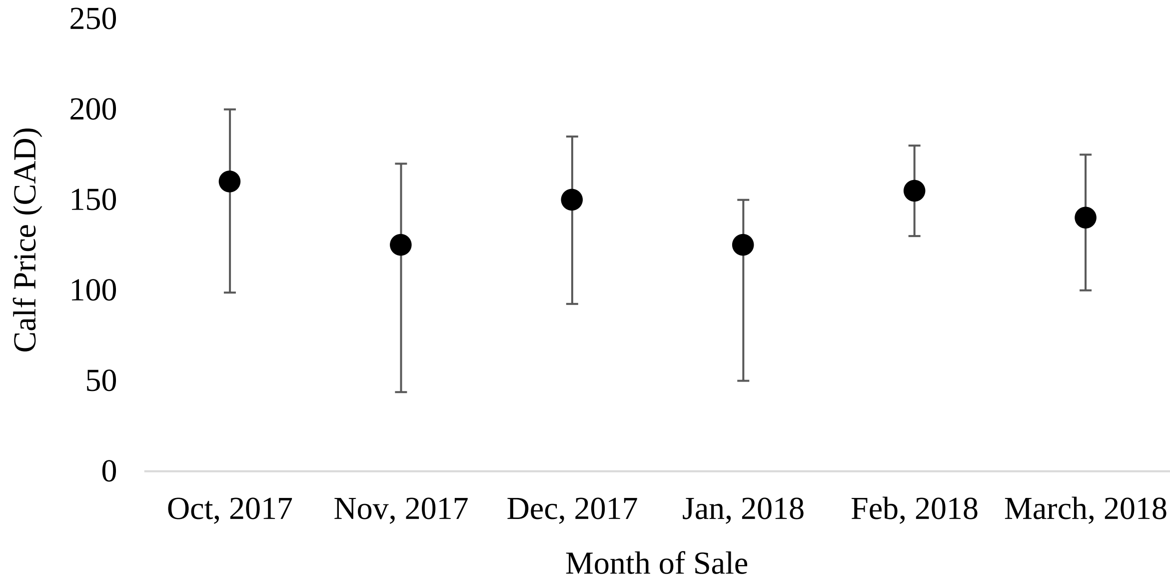
The median sale price of all 1661 calves was \$140 per calf with an interquartile range of \$70 to \$175. The price was not normally distributed (Shapiro-Wilk test $P<0.001$), but rather calves were more frequently sold at specific values (e.g. \$50, \$100, \$200), and the distribution was slightly skewed due to the high percentage of low-value calves (Figure 3.1).

Figure 3.1. Number of Holstein calves sold for different prices at a commercial auction market from October 1, 2017 to March 31, 2018 in British Columbia, Canada.



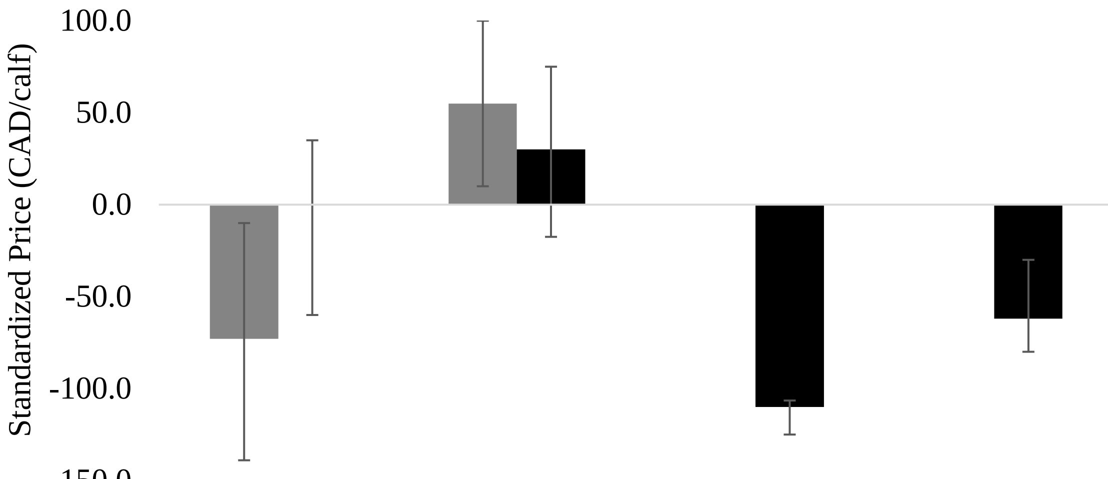
At the time of sale, 46 of the 1661 calves (2.8%) were declared “no sales” and 179 (10.9%) were sold for \$10 or less. The 6 assessed calves that were unsold had a mean (± SE) of 0.9 ± 0.4 health abnormalities versus 0.2 ± 0.0 for other calves, and their weight averaged 35.2 kg ± 2.3 kg versus 47.5 ± 0.4 kg for other calves, indicating that no-sale calves were generally small and in poor health. Calf price appeared to be lower in November and January (Figure 3.2).

Figure 3.2 Median ± interquartile range of the price per calf recorded for 1661 calves sold through a commercial auction market in British Columbia, Canada from October 16, 2017 until March 19, 2018.



There were 37 female calves (27 Holstein, 9 beef, and 1 Brown Swiss) and 1624 male calves (1531 Holstein, 47 beef, 27 Jersey and 19 Brown Swiss) observed. Median standardized price for Brown Swiss and Jersey calves was lower, and calves with beef breeding sold for more (Figure 3.3). Overall, female calves sold for lower prices, but this depended on their genetics.

Figure 3.3. Median and interquartile range of the standardized price for female and male calves with Holstein, Beef, Jersey and Brown Swiss genetics.



	Holstein	Beef	Jersey	Brown Swiss
Females	-73.0	55		
Males	0.0	30	-110	-62

Calf health at the auction was highly variable, with 20% of calves having at least one abnormality, most commonly a swollen and painful navel (Table 3.1).

Table 3.1. Number and percentage of calves with normal and abnormal health scores of 360 calves assessed before sale at a commercial auction in British Columbia, Canada

Health Score	**Abnormal (n)**	**Normal (n)**	**Percent Abnormal**
Attitude	7	353	2%
Ocular/Nasal	14	346	4%
Cough	8	352	2%
Joint	4	356	1%
Navel	43	317	12%
At Least One Abnormality	72	288	20%

Calves had a mean ± SD HG of 82.9 ± 5.0 cm, corresponding to 47 ± 8 kg BW based on the cubic formula by Heinrichs et al. (1992). The relationship between HG and price was linear, with calves receiving approximately $11 more for every extra cm (Table 3.2). Regression analysis confirmed that calves with beef genetics were sold for higher prices than Holstein calves. Calves with a depressed attitude also sold for less. Only 10 beef calves and 7 depressed calves were available for analysis, resulting in a high SE.

Table 3.2 Final linear regression model evaluating the effect of calf condition on standardized price for male dairy calves at a commercial auction in British Columbia, Canada

Variable		**n**	**Coefficient (CAD)**	**SE**	***P***
Intercept			-894.8	39.5	<.0001
Heart Girth		348	10.7	0.5	<.0001
Attitude	Alert	341	Referent		
	Depressed	7	-44.6	16.4	0.007
Breed	Holstein	338	Referent		
	Beef Crossbred	10	37.1	13.6	0.007

In Nova Scotia, 62% of calves were marketed as “average” rather than “good” quality (Altantic Stockyards Limited, 2019), and in Quebec, 18% of Holstein veal calves were of “divers” rather than “good” or “average” quality (Les Producteurs de bovins du Québec, 2019). In Nova Scotia, the weighted mean price for “average” bob calves was $36 and for “good” calves was $156. In Quebec, the mean price for “divers” calves was $0.48 per lb and for “good” and/or “average” calves was $1.23/lb.

3.4 Discussion

Calves sold for a wide range of prices, with some calves being marketed with health abnormalities or at a light weight that were of little to no commercial value. This finding coincides with studies from Eastern Canada showing dairy cattle are sometimes marketed in poor condition (Moorman et al., 2018; Marquou et al., 2019). Many factors contribute to poor calf conditioning; these include the housing and treatment costs of caring for unhealthy or small calves at their dairy farm of origin, and logistic challenges related to infrequent selling opportunities, but this has not been systematically evaluated.

Calves sold in November and January were priced lower compared to other months. Seasonality of price at auction markets has been documented in Quebec, Ontario and Nova Scotia, with prices ranging from $30 to approximately $520 and most typically dipping lower in September (Renaud et al., 2017). Seasonality is also observed in the beef industry, with lower prices typically seen in the fall when the supply of calves is greatest (Barham and Troxel, 2007). The lower prices in November and January may reflect poor weather, increased supply of calves, or other unmeasured factors. The effect of season on dairy calf price needs to be clarified.

Approximately 20% of calves in this study had an apparent clinical abnormality which did not include diarrhea or high body temperature. The most common abnormality observed was navel disease, as also noted by Marquou et al., (2019) who found omphalitis (swelling, discharge or pain of the navel) in 20.3% of calves at an auction in Quebec. Both studies found navel disease was not associated with standardized price; this could be because navel inflammation is difficult for buyers to assess in the auction environment. Calves showing depression (i.e., dull and unable or unwilling to rise) sold for less than calves with a bright and alert attitude, although this finding should be interpreted cautiously due to a small sample size. In a somewhat similar finding, Marquou et al. (2019) reported that calves with a general unhealthy appearance as judged by a veterinarian sold for less. While a depressed attitude is not a clinical diagnosis, it is easily recognizable and likely relates to overall calf health. In a recent study, 14% of calves had a depressed attitude upon arrival at a veal facility, and depression was seen more frequently in calves that were dehydrated (Pempek et al., 2017). It is therefore not surprising that calves which appeared bright and alert were sold for higher prices.

The weight of calves observed was very similar to the 47.5 ± 6.9 kg observed in Quebec, but unlike our study, Marquou et al. (2019) found that weight showed a quadratic relationship with price for veal calves as price was lower for both lighter and heavier calves. Veal calf nutrition is often strictly managed to target a specific market (e.g. a milk-based diet low in forage) (Webb et al., 2013), so it is possible that older calves in the Quebec market were discounted based on their exposure to feeds that would not fit the buyer's production system. Both studies showed a positive correlation between weight and price for most calves, which was expected as arrival weight has been linked to improved weight gain (Renaud et al., 2018d) and reduced mortality (Winder et al., 2016).

Calves in this study which were male and had beef genetics sold for higher prices, likely because beef breeds have higher feed efficiency and produce a more desirable carcass than dairy animals (Campion et al., 2009; Clarke et al., 2009). An increased price for dairy calves with beef genetics has been previously observed (Dal Zotto et al., 2009; Marquou et al., 2019), and represent an opportunity to increase profitability by selling cross-bred calves. In the beef industry, heifers are also typically discounted compared to steers destined for feedlots, presumably due to a higher cost of gain (Barham and Troxel, 2007). Decreased price of heifers purchased in our study may also have been due to an over-supply of dairy replacement animals, as predicted by a study that explored the use of sexed semen in the dairy industry (De Vries et al., 2008). This finding contrasts with Marquou et al. (2019) who found that female calves were sold for a higher price. It is possible that the different results relate to the regional market conditions for heifer calves, or that the result was affected by the limited number of female calves in our study.

In conclusion, many dairy calves were sold with health abnormalities that are easily detectable, and some were sold for very low prices or not sold at all. Heavier, male calves with beef genetics and calves with a bright, alert attitude sold for higher prices. These results suggest that dairy farmers could increase their returns by marketing calves with these characteristics. Furthermore, poor health condition of male calves upon arrival at calf rearing facilities has been related to increased mortality and reduced weight gains in veal production (Renaud et al., 2018d; a); therefore, calves sold with health abnormalities are at risk of limited productivity and reduced welfare. More investigation is warranted to understand factors contributing to the sale of unhealthy animals and to evaluate strategies to ensure male dairy calves are in robust condition when they are marketed.

Chapter 4: General Conclusions

The primary objective of this research was to evaluate the condition of male dairy calves at their dairy farm of origin and explore factors that influence their sale price and subsequent health outcomes. A number of recent studies have evaluated male dairy calf condition upon arrival at rearing facilities and found that calves can arrive dehydrated and suffering from navel, enteric and respiratory diseases (Pempek et al., 2017; Renaud et al., 2018d). These authors have suggested that suboptimal care of male calves on dairy farms likely contributes to poor calf condition upon arrival, but calves have not been previously followed from their dairy farm of origin to a calf rearing facility. This chapter will discuss the main conclusions of my research, some of the strengths and limitations, and ideas for future studies.

4.1 Thesis Findings

Following our main objective, we found that at least one clinical abnormality was noted in 37% of calves at the time when they were shipped from their farm of origin, primarily diarrhea and navel disease. Some farms shipped calves in good health, and had low levels of FTPI, but others did not. Similar variation in calf management has been observed in previous studies of heifer calf rearing (Atkinson et al., 2017), and a recent study of male calves (Shivley et al., 2019). Similar levels of diarrhea, respiratory disease, and navel inflammation were observed in calves assessed upon arrival at veal farms in Ohio (Pempek et al., 2017) and Ontario (Renaud et al., 2018d), and among calves assessed at an auction market in Quebec (Marquou et al., 2019). Together, these studies suggest navel disease is observed in 10-26% of calves, 6-17% have evidence of diarrhea, and around 1% have respiratory disease. The importance of calf health upon arrival at veal facilities has been emphasized by studies evaluating their growth, morbidity, and mortality (Pardon et al., 2015; Renaud et al., 2018a; d). My study supports the need for improvement in the management of male dairy calves at their farm of origin, especially navel and enteric health, to protect their health and welfare at calf rearing facilities.

Most previous research has not evaluated age as a risk factor, as calf age is generally unknown to veal producers. Interestingly, age was not associated with health outcomes in our study, but lower weight was associated with reduced sale price and greater odds of diarrhea treatment. Other studies have found calves with a lower body weight at arrival are at higher risk for mortality in the first weeks at veal facilities (Bähler et al., 2012; Winder et al., 2016). It is possible that larger calves with more body reserves are better able to handle the transition between farms, and that age is less important. This is important for policy development as regulations in New Zealand, the EU, and Canada specify a minimum age for calves before transportation, but do not specify the weight they should reach. Furthermore, as calf age is not easily tracked, weight may be a more convenient measure that could be useful in determining calf fitness for transport.

The economic value of male dairy calves may limit the care they receive and influence marketing practices (Renaud et al., 2017). Chapter 3 documents a wide variation in prices paid for male calves, with a substantial proportion of calves sold for low prices or not sold at all. This reflects variation in the quality of calves being marketed by dairy farms, although market fluctuation also plays a role. Our study supports previous research showing that calves that are small and unhealthy are sold for lower prices, and calves with beef genetics are of higher value (Marquou et al., 2019). The practice of transporting and marketing dairy calves in poor condition is a widespread animal welfare problem.

4.2 Strengths and Limitation

This study builds on previous research which suggests the quality of care and marketing practices for male dairy calves can predispose them to poor health outcomes at calf rearing facilities. A strength of this study was the number of calves evaluated before transportation which allowed characterization of the ranges of age, weight and health condition of calves sold from 17 dairy farms. One of the limitations was an inability to follow all the calves to the calf grower, resulting in smaller sample size for analysis of immediate health deterioration, morbidity, and mortality. Additionally, the different management at the dairy farms and the 2 calf growers introduced variability that had to be accounted for in the regression models. These factors decreased the power to detect differences in the calf characteristics that could have contributed to poor health outcomes at this sample size. In future studies, improved data collection at the calf grower would increase the sample size and may reveal more risk factors related to calf condition at the farm of origin.

Despite challenges with consistent data collection, a strength of this research is its applicability to producers, as the research was conducted on commercial farms. However, the ability to generalize the results is a limitation as the results are based on a convenience sample of 17 dairy farms from one region in British Columbia, and 2 calf growers from Alberta. Encouragingly, the 17 dairy farms took an interest in the controversial topic of male calf welfare and allowed evaluation of their calves. In the future, a broader survey could reveal regional differences in calf condition, and farm-level factors such as housing conditions, milk provision, and dam vaccination that may also influence male calf health.

Across calf health research there is an unfortunate lack of consistency with disease diagnosis and scoring. This study used a frequently cited and convenient health scoring system to assess calf condition (McGuirk and Peek, 2014). However, for respiratory disease the scoring criteria have not been well validated, and newer research has attempted to improve the system by determining the diagnostic weight of different clinical signs (Love et al., 2014). The use of thoracic ultrasonography has been advocated for diagnosis of BRD (Ollivett et al., 2015; Buczinski et al., 2016), and would have improved the sensitivity and specificity of our findings. For diarrhea, fecal consistency is considered a gold standard, and a 4-point system, often based on Larson et al. (1977), has been used in many studies. However, fecal consistency may not relate to systemic signs of disease (Studds et al., 2018), and many calves with watery feces do not develop further clinical signs related to bacteremia (Constable, 2004). Moreover, morbidity estimates at the calf growers in this study were based on treatment data. This strategy has been previously used (Waltner-Toews et al., 1986c; Windeyer et al., 2014), but relies on the clinical assessment and recording accuracy of farm staff, and may under- or over-estimate the prevalence of disease. While this study aimed to balance the convenience of assessment with validated, accurate methods, the lack of a simple and clinically relevant gold standard for diagnosis of calf diarrhea and respiratory disease is a limitation of this and other calf health studies.

4.3 Future Research

Calves that receive inadequate colostrum, are small, and have abnormal navels and a depressed attitude tend to receive lower prices at auction markets and have worse health outcomes at calf growers. Farms may not have enough space, skilled labour, or sale opportunities to ensure calves are in good condition before transportation, and the increased price received for high-quality calves may be insufficient to cover the associated costs. Further investigation into the economic feasibility of selling large, robust calves may help farmers to determine how best to provide high-quality care to their male calves. A logical first step would be to evaluate the important factors influencing farmers' decisions regarding male calf care and marketing. Investigating the importance of factors such as market fluctuation, facility requirements for calves, and labour availability may help reveal areas where farmers could benefit from education, market development, or policy changes. As calves with beef genetics can receive a higher price – which may in turn justify a higher level of care- further investigation of this strategy in a reproductive program for dairy herds would be beneficial.

Clarification of criteria for fitness for transport for calves, including optimal age and weight, would also inform policy development. Currently, a minimum age is used in New Zealand and the EU, but in many parts of the world age cannot be verified after calves leave their farm of origin. Furthermore, a young age of transport may not be associated with worse health outcomes. It may be better to regulate transportation based on a minimum weight, but further study of calf health outcomes should be completed over a wider range of ages. The ideal study would be a controlled trial, or a larger epidemiological study that accounted for differences in calf care on dairy farms, to determine the optimal calf conditions for transportation.

One of the surprising findings of this research was that some farms reported calves picked up very early in the morning were generally not fed before transportation. This would result in an estimated 36 hours without feed. Under natural conditions, neonatal calves suckle their dam 8 to 12 times daily (Reinhardt and Reinhardt, 1981). Feed withdrawal in young dairy calves has been associated with a drop in serum glucose and body weight (Fisher et al., 2014), so this practice likely increases the stress of transportation. However, Knowles et al. (1999) found that feeding calves during a transportation rest stop resulted in few improvements in blood parameters indicative of calf condition in the short term. Unfortunately, this study did not measure feed withdrawal or other health parameters that could have been affected by midtransport feeding. Further investigation is warranted on the optimal timing to feed calves before or during long-distance transportation.

4.4 Conclusion

This thesis contributes to understanding the condition of male dairy calves that are sold and transported from dairy farms. Calves are sometimes transported at a young age and light weight, displaying disease symptoms that are easily identified. These findings indicate a need for improvements in colostrum provision and other management practices for male dairy calves before they are transported. Further clarification on the optimum age and weight for shipment of calves is necessary to inform policy and protect male dairy calf health and welfare.

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