DISSERTATION

EXPLORING ANIMAL WELFARE THROUGH AN INVESTIGATION OF VETERINARY EDUCATION AND ON-FARM ASSESSMENTS OF DAIRY CALF WELFARE

Submitted by

Chelsey B. Shivley

Department of Animal Sciences

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Doctoral Committee:

Advisor: Temple Grandin

Franklyn B. Garry
Terry E. Engle
Bernard E. Rollin
Martha L. Kesel

ABSTRACT

EXPLORING ANIMAL WELFARE THROUGH AN INVESTIGATION OF VETERINARY EDUCATION AND ON-FARM ASSESSMENTS OF DAIRY CALF WELFARE

Animal welfare encompasses many different areas, including science, ethics, economics and law. Veterinarians have an opportunity to serve as leaders in the field of animal welfare due to their interaction with all aspects of animal use. In order to do so, they must be properly trained, and veterinary curricula were evaluated for courses related to animal welfare, ethics, and behavior. Consumers are concerned with how animals are managed, and aspects of welfare of preweaned dairy calves, including colostrum quality, passive transfer status, average daily gain, and bull calf management, were evaluated.

The objective of the first study presented in Chapter III was to explore the extent to which veterinary colleges and schools accredited by the AVMA Council on Education (COE) have incorporated specific courses related to animal welfare, behavior, and ethics. The design included a survey and curriculum review. The sample included all 49 AVMA COE–accredited veterinary colleges and schools (institutions). The study consisted of 2 parts. In part 1, a survey regarding animal welfare, behavior, and ethics was e-mailed to the associate dean of academic affairs at all 49 AVMA COE–accredited institutions. In part 2, the curricula for the 30 AVMA COE–accredited institutions in the United States were reviewed for courses on animal behavior, ethics, and welfare. Seventeen of 49 (35%) institutions responded to the survey of part 1, of which 10 offered a formal animal welfare course, 9 offered a formal animal behavior course, 8 offered a formal animal ethics course, and 5 offered a combined animal welfare, behavior, and

ethics course. The frequency with which courses on animal welfare, behavior, and ethics were offered differed between international and US institutions. Review of the curricula for the 30 AVMA COE–accredited US institutions revealed that 6 offered a formal course on animal welfare, 22 offered a formal course on animal behavior, and 18 offered a formal course on animal ethics. Results suggested that AVMA COE–accredited institutions need to provide more formal education on animal welfare, behavior, and ethics so veterinarians can be advocates for animals and assist with behavioral challenges.

Animal welfare is an important aspect of veterinary responsibility, yet the current curriculum at most veterinary schools provides little formal training in this field. The Animal Welfare Judging and Assessment Contest provides an opportunity for students to learn about general animal welfare principles, challenging them to apply critical reasoning skills in a competitive environment. The fourth chapter provides an overview of the contest and an example of how Colorado State University educates and prepares its students.

Passive transfer of immunity is essential for the short- and long-term health and welfare of dairy calves. The objective of the study presented in Chapter V was to evaluate factors associated with colostrum quality and passive transfer status of U.S. dairy heifer calves. This study included 102 dairy operations in 13 states that participated in the calf component of the National Animal Health Monitoring System's Dairy 2014 study. This longitudinal study focused on dairy heifer calves from birth to weaning and was conducted over an 18-mo period. Data analysis included 1,972 Holstein heifer calves. The mean colostrum IgG concentration was 74.4 g/L, and 77.4% of samples had colostrum IgG levels greater than 50 g/L. The mean calf serum IgG concentration was 21.6 g/L, and 73.3% of calves had serum IgG levels greater than 15 g/L. Backward elimination model selection in Proc Mixed of SAS® was used after univariate

screening (P<0.2) to determine which factors were most important for determining colostrum IgG levels. The final model for colostrum IgG included the colostrum source and a categorized temperature and humidity index value (THI) for the month prior to calving. Colostrum IgG concentration was highest for third+ lactation dams (84.7 g/L) and lowest for commercial colostrum replacers (40.3 g/L). Colostrum IgG was highest for THI ≥70 (72.6 g/L), and lowest for THI <40 (64.2 g/L). Factors most important for predicting calf serum IgG levels were evaluated using a backward elimination model selection in Proc Mixed after univariate screening (P<0.2). The final model for serum IgG included region, heat treatment of colostrum, colostrum source, timing to first feeding, volume of colostrum fed in the first 24 hours, the age of the calf at blood sampling, and colostrum IgG concentration. Serum IgG level was highest for calves that received colostrum from first lactation dams (25.7 g/L), and lowest for calves fed commercial colostrum replacer (16.6 g/L). Serum IgG level was higher for calves fed heat-treated colostrum (24.4 g/L) compared with calves fed colostrum that was not heat-treated (20.5 g/L). Serum IgG level was positively associated with the volume of colostrum fed in the first 24 hours and colostrum IgG concentration, and negatively associated with the number of hours from birth to colostrum feeding and the age (days) at blood collection. These results indicate that colostrum quality is affected by colostrum source and the climatic conditions during the month prior to parturition. The source, quality, timing of administration, and quantity of colostrum administered all influenced serum IgG levels.

The objective of the study described in Chapter VI was to evaluate average daily gain (ADG) in dairy heifer calves based on different health, feeding, and management practices, as well as environmental factors. This study included 102 operations in 13 states that participated in the calf component of the National Animal Health Monitoring System's Dairy 2014 study. This

longitudinal study focused on 1,410 Holstein heifer calves from birth to weaning and occurred over an 18-mo period. The mean ADG from birth to the final weight was 0.74 kg/day. Backward elimination model selection in Proc Mixed of SAS® was used after univariate screening ($P<0.2$) to determine which factors significantly impacted ADG. The final model included disease status, protein in the liquid diet (kg/day), milk pasteurization, direct-fed microbials in the liquid diet, a categorized average temperature and humidity index (THI) for the preweaning period, dam lactation number, bedding type, singleton vs. twin birth, *Cryptosporidium* shedding, and *Giardia* shedding. After controlling for other independent variables in the model, calves with no disease events gained 0.07 kg/day more than calves with one or more disease events. Within the range of observed kg of protein fed per day in the liquid diet, every additional 0.1 kg of protein fed per day equated to 0.02 kg/day of gain. Calves fed milk replacer (0.56 kg/day) gained less than calves fed pasteurized whole/waste milk (0.66 kg/day) and calves fed unpasteurized whole/waste milk (0.63 kg/day). Calves with a direct-fed microbial added to the liquid diet gained 0.06 kg/day less than calves without a direct-fed microbial added. Calves experiencing an average THI less than 50 during the preweaning period (0.66 kg/day) gained more than calves experiencing an average THI between 50 and 69 (0.61 kg/day), or greater than or equal to 70 (0.58 kg/day). Calves from first lactation dams (0.59 kg/day) gained less than calves from second (0.63 kg/day) or third or higher lactation dams (0.63 kg/day). Calves bedded with sand or no bedding (0.48 kg/day) gained less than all other bedding types. Single calves gained 0.07 kg/day more than twins. Calves negative for *Cryptosporidium* or *Giardia* at the time of sampling gained more than calves that were positive for *Cryptosporidium* or *Giardia.* These results highlight the importance of feeding an appropriate quantity and quality of a liquid diet, keeping calves healthy, and mitigating the effects of temperature and humidity on ADG.

The objective of the study presented in Chapter VII was to survey management practices of preweaned dairy bull calves and compare these practices to those used for preweaned heifer calves on the same operations. This study was conducted as part of the National Animal Health Monitoring System's Dairy 2014 study, and included a convenience sample of 42 operations in 10 states. Overall, 7.4% of bull calves were stillborn. Stillbirth percentage for all calves on the 42 operations was 5.8%. Of the 96.3% of bull calves that received colostrum; 95.4% received colostrum by hand feeding only, 3.1% received colostrum by hand feeding and suckling, and 1.5% received colostrum by suckling only. No heifer calves on the 42 operations received colostrum by suckling only. Bull calves received colostrum 4.3 h after birth, compared with 2.9 h after birth for heifer calves. At the first feeding, bull calves received 3.1 L of colostrum, plus 1.7 L in all subsequent feedings for a total of 4.8 L of colostrum in the first 24 h, compared to a total of 5.4 L of colostrum in the first 24 h for heifer calves. Most operations (97.6%) sold bull calves prior to weaning, at an average age of 7.6 days. On average, 2.4% of bull calves died prior to leaving the operation. Most operations did not dehorn bull calves (78.6%). Of the 22.2% of operations that did dehorn bull calves, 66.7% of operations dehorned using hot irons at an average age of 19.8 d. Only 11.1% of operations that dehorned bull calves used analgesics/anesthetics when dehorning. Heifer calves were dehorned on 88.1% of operations, with hot iron being the most commonly used method. Anesthetics/analgesics were used when dehorning heifer calves on 23.9% of operations. Most operations did not castrate bull calves (72.2%). Of the 27.8% of operations that did castrate bull calves, 70.0% of operations used a band at an average age of 6.3 weeks; 14.3% of operations (n=1) used analgesics/anesthetics. Knife castration was used by 30.0% of operations, at an average age of 14.7 weeks with none of these operations using analgesics/anesthetics for castration. Overall, bull calves on these

operations were managed differently from heifer calves regarding colostrum feeding and the use of analgesics/anesthetics for painful procedures. These results highlight the need to evaluate passive transfer in bull calves to monitor colostrum management practices and educate producers and veterinarians in the value of using analgesics or anesthetics for painful procedures in bull calves.

Overall findings show that more formal courses related to animal welfare, ethics, and behavior are needed for veterinary students. The Animal Welfare Judging and Assessment Contest provides an extracurricular opportunity for veterinary students to learn about animal welfare. Colostrum management and passive transfer in dairy heifer calves has improved, though overall average daily gains for preweaned heifer calves were below current recommendations. Improving the quantity and/or quality of the liquid diet and preventing disease can improve growth. Dairy bull calves are managed differently than heifer calves, and the use of pain management for painful procedures is minimal. Further education regarding the value of the use of pain management needs to be done.

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graduate, and veterinary students helped me with my various research projects, and they have provided support during my program.

None of the information regarding the dairy industry would have been possible without the participation of individual dairy producers in the Dairy 2014 study. Thank you to all of them for taking time away from what they love, caring for dairy cattle, to answer our questions in order to learn about the industry.

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CHAPTER I: INTRODUCTION

The field of animal welfare represents a multidimensional arena that incorporates science, ethics, law, politics, and economics, and applies these concepts to all aspects of animal use, including animals used for food and fiber, entertainment, research, companionship, service, and many others. In recent times, the general society has become increasingly interested in the care and management of animals, creating a demand for animal welfare research. While research in this area can help devise measures for assessing animal welfare, and benchmarking current practices to measure progress, ultimately ethical decisions must be made to determine what is deemed acceptable animal welfare. Animal welfare must be assessed at an individual animal level, though broad concepts can be applied to the bigger picture of how the lives of animals and humans intersect.

The complexities and nuances of animal welfare are what excite me about the topic, as well as the ability to think about current issues in new and creative ways. As a lifelong animal lover, I decided to become a veterinarian at the age of two. I checked off all of the required boxes to get accepted to veterinary school, including years of 4-H, volunteering at veterinary clinics, and heading to Michigan State University (MSU) for my undergraduate degree in zoology. It was there that I learned about animal welfare by participating in the Animal Welfare Judging and Assessment Contest, ultimately changing the trajectory of my life.

During my second year of veterinary school at MSU, the American Veterinary Medical Association (AVMA) and the Association of American Veterinary Medical Colleges (AAVMC) partnered with MSU to host the "Swimming with the Tide: Animal Welfare in Veterinary Medical Education and Research" symposium, and I was lucky enough to attend most of the

talks in between classes. I will never forget listening to Dr. Bonnie Beaver describe the proposed American College of Animal Welfare (ACAW), and the many roles of veterinarians in the field of animal welfare. Although ACAW was still in its infancy when I graduated from veterinary school, I knew my role as a veterinarian was going to be in the field of animal welfare.

Most PhD programs are designed to explore one particular topic in depth, with studies designed to learn about the topic from all angles. Although it might not initially be clear to the reader, my program fit this definition of a PhD, with the common thread of animal welfare. My goal was to explore the field of animal welfare from several different angles. In my opinion, my veterinary education lacked enough training on animal welfare and animal ethics issues, motivating me to conduct the first survey regarding current veterinary curricula practices related to animal welfare, animal behavior, and animal ethics. During my time at Colorado State University (CSU), I created the CSU Animal Welfare Judging Team, now comprised of undergraduate, graduate, and veterinary teams, and I developed a course to prepare students for the annual Animal Welfare Judging and Assessment Contest. I want to share this model as a method of teaching animal welfare, leading to the second paper – a teaching tip on how to start an animal welfare judging team.

During my program, it was important to me to gain field experience, and I was fortunate to work with the USDA National Animal Health Monitoring System (NAHMS) on the Dairy 2014 Study. While I was exposed to all aspects of the study, I focused on the longitudinal heifer calf study and the bull calf study. I gained valuable experience by enrolling four Colorado dairies and collecting data for 18 months, including collecting colostrum and serum samples, measuring calf growth, and interviewing the producers and calf handlers about management

practices (as well as becoming very skilled at collecting calf fecal samples). I also had access to a nationwide dataset, a true gift for a graduate student.

There are three chapters reporting the results of the calf studies. The first focuses on colostrum quality and passive transfer status in preweaned dairy heifer calves, as previous work had identified failure of passive transfer as a risk factor for poor calf welfare. The second chapter evaluated factors related to average daily gain in heifer calves during the preweaning period. Growth can be impacted by many different factors, making it a useful tool to assess overall calf management practices. The initial analysis for these two studies is shown in Figure 1.1. The third chapter focused on the management of dairy bull calves prior to leaving the operation of origin, a previously unexplored area.

While this dissertation provides a culmination of my scientific research studies conducted during my time at CSU, I feel that some of my most important work is missing. Being able to create the Animal Welfare Judging Team not only gave me valuable teaching experience, but I was able to create a culture of animal welfare at CSU and bring people with an interest in the topic together. While my work at the USDA has led to interesting and important research findings related to dairy calves that I am excited to share with the scientific community, I am more proud of bringing that information directly to the people it impacts most: dairy producers. I was able to present to numerous dairy producers and veterinarians in Washington State, as well as create valuable feedback in the form of a report for all of the producers that participated in the study. If these producers change just one thing that will improve the management of dairy calves, then I feel that I have accomplished my goals.

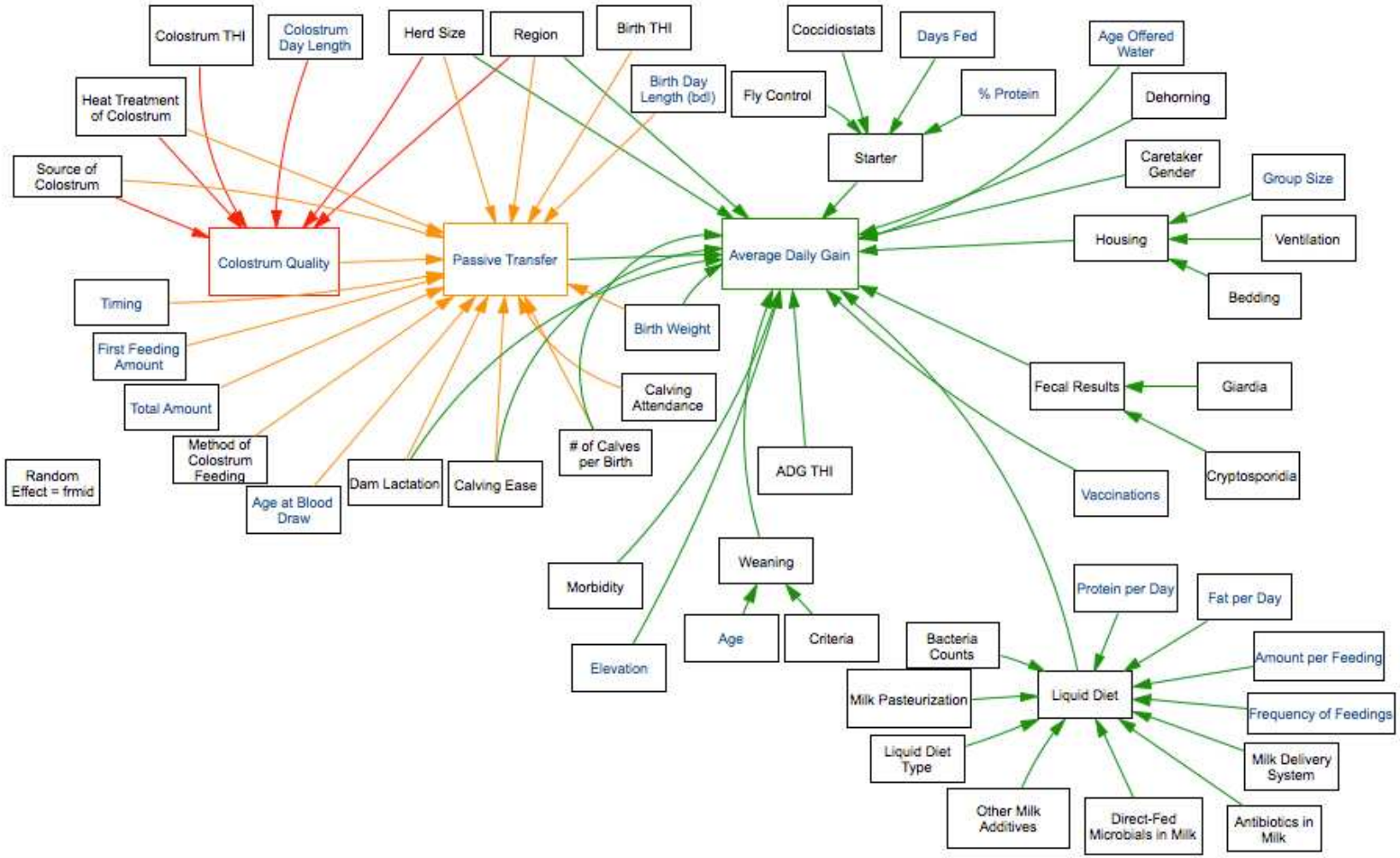

Figure 1.1. Initial Heifer Calf Analysis Plan. Continuous variables are shown in blue text, and categorical variables are shown in black text. Outcome variables included colostrum quality (colostrum IgG), passive transfer of immunity (serum IgG), and average daily gain (kg/day). Arrows are color-coded and connect initial predictor variables (included in the initial screening for the multivariable models) to outcome variables.

CHAPTER II: LITERATURE REVIEW

ANIMAL WELFARE

Animal welfare is defined by the American Veterinary Medical Association as how an animal is coping with the conditions in which it lives, and ranges on a spectrum from poor to excellent (AVMA, 2015). While a seemingly simple definition, animal welfare is a multi-dimensional issue, and includes ethics, values, science, economics, and politics (Lund et al., 2006). Animal welfare science necessitates a multifactorial approach to assess the physiological status of an animal (such as heart rate, cortisol fluctuations, and immune functioning), the behavior of an animal (including preference testing, motivation testing, and prevalence of stereotypic behaviors), and a combination of both to assess the subjective experience of an animal (Fraser, 2008). While animal welfare science can provide data, the acceptable ranges for these data can only be answered with animal ethics (Fraser et al., 1997). Ultimately, a combined approach using scientific inquiry and ethical reflection regarding animal use is required to fully investigate animal welfare, since neither science nor ethics can solve animal welfare issues (Fraser, 1999).

Animals have played many different roles in the lives of humans over the past 10,000 years, when animal domestication began. In the past 100 years, there has been a shift in the views of the general public on animal use, what Rollin has termed the "emerging social ethic for animals" (Rollin, 1994). He argues that industrialized agriculture is one of the primary drivers for this new social concern (Rollin, 2003). Historically, animal husbandry required a fair contract between humans and animals, and the traditional ethic of animals focused only on preventing cruelty. According to Rollin, the industrialization of agriculture has led to significant

animal suffering not due to cruelty, but by not allowing an animal to live according to its telos. This requires a new ethic in order to help protect animals from suffering at the expense of humans. Other areas of animal use are not exempt from this emerging social ethic for animals; animals in research were one of the first areas to gain awareness from the general public. Out of this new belief system developed the science of animal welfare, in order to determine how to best meet animals' needs while they are in our care (Broom, 2011).

Animal welfare has been divided in to three primary areas of concern: basic health and functioning of an animal, an animal's affective states (including pain, hunger, stress, and pleasure), and the naturalness of an animal's environment and the ability to perform natural behaviors (Fraser, 2008). While there is significant overlap between these three areas, placing greater emphasis on one over the others can lead to significantly different conclusions about animal welfare. According to Dawkins (2006), good animal welfare begins with overall good health. An animal that is injured, diseased, or in pain is experiencing both physical and mental suffering, therefore these conditions must be prevented or promptly diagnosed and treated. Measures such as morbidity and mortality rates, body condition scoring, locomotion scoring, and fertility can all be used to assess the physical health and functioning of an animal (Whaytt et al., 2003; Fraser, 2009). Often, veterinarians and producers focus on the health and functioning of an animal when assessing overall welfare, failing to recognize the importance of the subjective experience of the animal (Fraser, 2008). While some believe that an animal's emotional state cannot be studied scientifically, Duncan has devoted much of his career to understanding animals' emotions through techniques such as preference testing and motivational studies (Duncan, 1996). The engagement in certain activities can give an indication of an animal's emotional state, such as stereotypic behaviors when in a negative state, and play behavior when

in a positive state (Fraser and Duncan, 1998). Naturalness is not part of animal welfare per se, but comparing an animal to its wild counterparts can provide some insight into why it performs certain behaviors, and it can give ideas about environmental enrichment opportunities (Broom, 2011). Another important point is that nature can be cruel; animals in the wild face predation, starvation, and disease, all of which negatively impact animal welfare.

One of the first attempts to identify areas of farm animal welfare concern occurred in the United Kingdom in 1965 with the Farm Animal Welfare Advisory Council. This advisory council was created in response to Ruth Harrison's book *Animal Machines* (Harrison, 1964), which highlighted her concerns about industrial animal agriculture. The report from that council is known as the Brambell Report, and after several revisions, the final result was what is now known as the Five Freedoms of Animal Welfare (Brambell, 1965). The Five Freedoms provide an expectation that negative aspects of animal welfare will be eliminated for animals under human care, both for physical and mental suffering.

The Five Freedoms of Animal Welfare:

1. Freedom from hunger and thirst – by ready access to fresh water and a diet to maintain full health and vigor.
2. Freedom from discomfort – by providing an appropriate environment including shelter and a comfortable resting area.
3. Freedom from pain, injury, or disease – by prevention or rapid diagnosis and treatment.
4. Freedom to express normal behavior – by providing sufficient space, proper facilities, and company of the animal's own kind.
5. Freedom from fear and distress – by ensuring conditions and treatment which avoid mental suffering.

The Five Freedoms have provided an excellent starting point for animal welfare assessments, and they have been used in research settings, animal industry guidelines, legislation, and education. Critiques of the Five Freedoms have noted that they only focus on the elimination of negative aspects of animal welfare, with no consideration for positive animal welfare (McCulloch, 2012). Additionally, they provide more of a theoretical framework for thinking about animal welfare than a practical tool for animal welfare assessment (McCulloch, 2012). Another framework for animal welfare assessment suggested by Mellor and his colleagues is the Five Domains of Animal Welfare, an extension of the Five Freedoms (Mellor and Stafford, 2001).

The Five Domains of Animal Welfare:

1. Water deprivation, food deprivation malnutrition – prevented or corrected by ready access to fresh water and an appropriate diet in sufficient quantities and with a composition that maintain full health and vigor.
2. Environmental challenge – prevented or corrected by providing a suitable environment including shelter and a comfortable resting area, whether outdoors or indoors.
3. Disease, injury, functional impairment – prevented or corrected by prevention or rapid diagnosis and treatment.
4. Behavioral or interactive restriction – prevented or corrected by providing sufficient space, proper facilities, and the company of the animal's own kind.
5. Mental (and physical) suffering – minimizing the conditions that produce unacceptable levels of anxiety, fear, distress, boredom, sickness, pain, thirst, hunger, and so on.

Domains 1-4 focus on the physical health and functioning of an animal, and they all contribute to domain 5, the mental and/or emotional state of an animal. An extension of this idea

was introduced that added positive emotional states to domain 5, and optimal welfare is achieved when negative mental states are avoided and positive mental states are promoted (Green and Mellor, 2011). The quality of life concept of animal welfare explains the extension of the five domains as a transition from just preventing mistreatment to providing an animal with a life worth living (Green and Mellor, 2011). The utility of using quality of life to assess an animal's welfare is not yet fully defined, and currently involves subjective assessments.

Concurrent with the evolution of animal welfare science, perceptions about animal welfare have been changing over the past several decades. As the size of farms has increased, the number of farms has decreased, and the number of people involved with agriculture is now less than 2% of the American population (USDA-NASS, 2012). As people get further removed from the farm, they become less familiar with the everyday management of animals used for the production of food and fiber (Grandin, 2014). Recently, consumers have had an increased interest in knowing where their food comes from, and consumer concern for animal welfare is changing. Production systems designed for improved animal welfare result in increased costs due to increased inputs (i.e. more space, increased labor) and reduced productivity (often due to lower stocking densities) (Bornett et al., 2003). Consumer concern for animal welfare can lead to policy changes, yet does not always equate to a willingness to pay for the premium product (Nocella et al., 2010). Transparency related to animal welfare practices, assessments, and labeling systems is needed to meet the demands of consumers (Blokhuis et al., 2003). Producers and consumers are not completely in agreement about animal welfare either; producers tend to rate overall animal welfare as good, yet consumers believe current animal agriculture is less than optimal (Te Velde et al., 2002; Vanhonacker et al., 2008). Consumers placed a greater emphasis on practices that cause pain and stress, and the ability to perform natural behaviors, compared

with producers (Vanhonacker et al., 2008). A person's viewpoint on animal welfare relates back to their overall value system and outlook on life (Cembalo et al., 2016). A survey of animal science faculty members in the U.S. showed that overall more than 90% of respondents supported general animal welfare principles, yet only 32% of respondents were concerned about castration without anesthesia (Heleski et al., 2004). This is a concern because if animal science faculty have different animal welfare concerns than consumers, then potentially research into the areas most important to consumers will not get done.

A basic understanding of the history of animal welfare, as well as the general beliefs held by different stakeholders, is important for guiding animal welfare research. Animal welfare scientists must consider the sometimes conflicting needs and desires of the general public, animal producers, and the animals themselves, when asking research questions regarding animal welfare. Due to its multifaceted nature, animal welfare research benefits from collaborative research efforts by scientists with different areas of expertise, such as physiology, behavior, and veterinary medicine.

VETERINARY CURRICULA RELATED TO ANIMAL WELFARE

Veterinarians can be seen as the first line of defense for animal welfare since their primary role is of guardians of animal health. While this role is clearly established, the veterinarian's role in animal welfare is less distinct (Wilkins, 2008). In 2010, the American Veterinary Medical Association revised the veterinary oath to include the protection of animal health and *welfare* (Nolen, 2011). Due to the veterinary interface with all aspects of animal use, including companion animals, agricultural animals, animals in research, animals in entertainment, and many others, veterinarians are perfectly poised to be leaders in the field of animal welfare. Not only do veterinarians touch all animals, they also interact on a daily basis

with people from all different backgrounds, including their clients as well as animal rights activists (Ladewig, 2008). Veterinarians are trained to understand scientific principles, and they are trusted by most, meaning the profession has the ability to influence animal welfare standards (Kipperman, 2015). Unfortunately, veterinarians are not yet seen as leaders in animal welfare (Croney, 2010). One of the greatest challenges to becoming leaders in animal welfare will be developing a consensus about animal welfare in general, as well as specific animal welfare issues. The profession has discordant views about whether animals are means to an end or the more popular view that animals are companions (Croney, 2010). Additionally, veterinarians generally focus on the physical health of animals as the primary component of their overall welfare, while often neglecting their psychological, social, and behavioral needs. Part of this could be due to the lack of training in ethology in the veterinary curricula, and behavioral needs are outside of the comfort zone of many veterinarians (Algers, 2008). Similarly, Main identified the focus of veterinarians tends to be on the physical health of animals, yet this concept is changing to include more behavioral components and to utilize the concept of a life worth living (Anonymous, 2010). The only way forward is to dive deep into these issues as a profession to try to find areas of commonality and strive for continual improvement in animal welfare, starting in veterinary school.

An example of this using sow gestation housing was explored by Parsons and Deen (2015). Veterinarians who interact with the swine industry on a daily basis tend to focus on the welfare benefits associated with improved health and nutrition and decreased fighting between sows when housed individually in gestation stalls, placing greater emphasis on the sows' physical welfare. Veterinarians not involved with the industry focus more on the negative psychological attributes of individual sow housing of not being able to perform natural

behaviors, such as turning around. Different sections of the profession have placed greater emphasis on different aspects of the welfare implications of individual sow gestation housing without considering the issue in its entirety. What matters most is the experience of the animals, and both systems have positive and negative implications for sow welfare. Agreement within the profession is not the goal, but rather discourse and discussion in order to see the issue in a different way, and try to find new solutions to current challenges. Welfare issues are complex, and only by recognizing all of the nuances and competing interests can the veterinary profession seek a leadership role in this arena.

In order for the veterinary profession to become leaders in the field of animal welfare, all veterinarians must be trained on animal welfare science, including broad principles of animal welfare, the ethics of animal use, and the different values people use when conducting animal welfare assessments. Animal welfare is a complex, multidisciplinary topic that continues to evolve, and the education of veterinary students needs to follow the advances made in science in addition to the changing societal drivers (Main, 2010). According to Main, "all [veterinary] students need to understand the differences between welfare science (quantifying the impact of humans on animals), welfare ethics (exploring the moral treatment of animals by humans), and welfare standards and policy (defining how humans must treat animals)." While specific details of a course on animal welfare can vary, topics that must be included are definitions of animal welfare, positive and negative influences on animal welfare, animal welfare assessment, and evolving trends in consumer demand (Main, 2010). Drivers for the inclusion of animal welfare into the veterinary curriculum include government and policy shifts, student expectations, and changes in industry standards regarding animal welfare. A commentary by two veterinary students in 2010 from Louisiana State University and University of Missouri on the state of

animal welfare in their veterinary schools highlighted the lack of animal welfare training currently available for veterinary students in the United States (Colonius and Swoboda, 2010). They represented the growing voice of veterinary students who want to learn more about this important topic. Veterinary educators are also demanding inclusion of animal welfare into the already full curricula due to increasing demand by the general public for veterinarians to be knowledgeable of these issues (Beaver, 2005).

Because animal welfare is such a diverse topic, there are many important components that should be covered in a course. An understanding of the interface of facts and values will be important when making decisions regarding patient care as well as when advocating for animal welfare through policy (Carbone, 2010). Veterinary students need to learn their own value system, or the lens through which they view animal welfare, and they must learn to see the world through a different lens in order to effectively communicate with clients and the public. The profession needs to continually engage with producers, clients, the public, and all stakeholders to determine what should be incorporated into a course (Krehbiel, 2010). Animal welfare education should be a distinct course due to the multidisciplinary nature of the topic, as well as the complex junction of science and ethics, all of which take more than a few lectures to cover (Broom, 2005).

Animal welfare education in veterinary curricula is highly variable around the world. A recent survey in Croatia found that the attitude scores toward farm animals (higher=more empathetic toward animals) did not change in first year veterinary students after taking a course in animal welfare, yet the scores of students in their final year of veterinary school were lower than the attitude scores of first year veterinary students (Ostović et al., 2016). This is concerning since as veterinary students approached graduation, their empathy toward farm

animals declined, not preparing them to be advocates for animal welfare. A similar study conducted in the United Kingdom comparing first-year preclinical students, first-year clinical students, and final-year students found that students showed lower levels of empathy toward animals in their final years of school, but only in male students (Paul and Podberscek, 2000).

In Turkey, animal welfare education has been included in the veterinary curricula since 1895, and as of 2004, animal welfare specific courses were incorporated into the veterinary curricula (Gurler, 2007). There still exists disagreement among veterinary institutions in Turkey about what concepts to include in an animal welfare course, who should teach the course, and how the course should be taught (Gurler, 2007). In Australia, enrollment in an animal welfare course during the first year of veterinary school significantly improved overall attitudes of veterinary students toward animals, perhaps suggesting a different teaching strategy compared with Croatia (Hazel et al., 2011). A study done in the United States compared veterinary students who had taken a discussion-based animal welfare elective with veterinary students who had not taken the elective course. While both groups had similar actual knowledge levels on novel animal welfare topics, the students who had participated in the course were significantly more comfortable with educating themselves on the topic (Lord et al., 2010). Being able to educate yourself on animal welfare topics is an important skill for veterinarians to possess since the field is continually evolving, and new issues come up that might not have been relevant during their time in veterinary school and been covered in a course.

There are many different models currently available for teaching animal welfare to veterinary students. The Norwegian School of Veterinary Science has tried to fully incorporate their animal welfare research into training veterinary students with the use of new technologies, including virtual reality environments (Zanella, 2008). An elective course developed at The

Ohio State University included lectures on controversial animal welfare topics, student presentations of the scientific literature on both sides of these topics, followed by small group discussion on the topics (Lord et al., 2010). Student feedback on the educational model was overall positive, and students felt it was a rewarding introduction into the complexities of animal welfare issues. A computer-aided learning education resource was developed in the United Kingdom that included a lecture about the five freedoms followed by videos of animals in various husbandry situations, as well as quizzes, open-ended questions, and concept mapping (Kerr et al., 2013). When compared with a control group of students who did not participate in the course, the computer-aided learning program improved students' abilities to assess and report on the animal welfare of sheep during their farm placement. Hewson and colleagues summarized the animal welfare education for veterinary students at 13 international institutions located in Europe, North America, South America, and Australasia (Hewson et al., 2005). While each institution varied in the content covered, the teaching approach, and the methods used to assess students, all institutions required at least some coursework related to animal welfare. As of 2005, the University of Guelph veterinary students received little formal coursework related to animal welfare, despite having the Campbell Centre for the Study of Animal Welfare and numerous animal welfare experts on campus (Millman et al., 2005). At the University of Sydney, veterinary students received several years of training on animal welfare (McGreevy and Dixon, 2005).

Outside of the traditional confines of regular courses on animal welfare within the curriculum at each institution, there are a growing number of resources available online. The World Society for the Protection of Animals (now known as World Animal Protection) and the University of Bristol created a curriculum on animal welfare titled "Concepts in Animal

Welfare" (de Boo and Knight, 2005). The original curriculum contained 7 core modules and 23 elective modules on a variety of animal welfare topics. The program is currently on its third edition, with additions of modules on fish welfare and disaster management, and it is available free online (Anonymous, 2013; World Animal Protection, 2016). Another option for online learning about animal welfare includes MOOCs, or Massive Open Online Courses, such as the one developed by the University of Edinburgh and Scotland's Rural College using the platform Coursera.org (MacKay et al., 2016). Over a decade ago, Michigan State University recognized the challenge of needing to teach veterinary students about animal welfare, as well as the lack of room for another course in the curriculum and the relatively few people qualified to teach an animal welfare course. As a result, they developed an online, graduate level course in animal welfare assessment, with animal welfare scenarios serving as the basis of the course (Siegford et al., 2005; Siegford et al., 2011).

While all veterinary students should receive at least some training on animal welfare principles, there are additional programs for veterinarians seeking further training in the field after graduation. In the United States, the American College of Animal Welfare was recognized as a board specialty college within the AVMA in 2012 (Beaver, 2010; ACAW, 2016). In the United Kingdom, additional training on animal welfare, animal ethics, and animal law beyond what is required during veterinary school can be documented with a certificate (expertise level) or a diploma (high level of expertise) (Main et al., 2005). Hopefully these veterinary experts in animal welfare can help propel the profession forward as leaders in the field.

COMPETITIVE ANIMAL WELFARE JUDGING CONTESTS

Judging competitions and contests have been a tool for teaching students about agricultural concepts for over 100 years, and have included livestock judging, horse judging,

meat judging, wool judging, and dairy judging. This teaching tool has been used in 4-H competitions, FFA contests, as well as at the collegiate level. A survey of judging team alumni found that commonly cited personal benefits included communication skills, confidence, animal evaluation skills, and decision-making skills (McCann et al., 1992). Many of these alumni indicated that the judging team program was a part of their college selection decision, and as alumni, they have contributed to the college and/or the judging program. A survey of universities with agricultural programs found that 84.6% of the 39 respondents sponsored at least one animal related judging team (Field et al., 1998). Again, the most frequently stated outcomes of participation on a judging team included communication ability, logical decision-making, industry knowledge, and teamwork. Specific to dairy cattle judging, specific skills identified included critical thinking, self-discipline, situation analysis, decision making, organization, verbal expression and defense of decisions, all of which are critical life skills (Guthrie and Lee Majeskie, 1997). The judging team model has proven to be a successful way to teach students not only about animal agriculture, but learning necessary skills for a career in the agricultural industry.

In the early 2000s, this model was adopted as a method to teach university students about animal welfare. The first animal welfare judging team contest was hosted by Michigan State University in 2002, and there were 18 participants from Purdue University, University of Wisconsin, University of Guelph, and Michigan State University (Heleski et al., 2002; Waltman et al., 2002). Animal welfare scenarios were developed that included a variety of information about the management of several different animal species, including heart rate responses to handling and stress hormone responses to interventions. A survey administered after that first event found that 94% of students stated that their animal welfare knowledge had increased, and

100% of respondents thought the competition was a good idea, and they would encourage other students to participate (Waltman et al., 2002). Overall, the first competition was successful, and the program has continued to develop over the past 14 years. Additionally, this teaching model has been implemented at the 4-H level, with success in teaching a younger audience about animal welfare assessment (Andersen et al., 2006).

While modeled after traditional judging contests, the animal welfare judging contests have some unique differences. A live animal/team assessment scenario has been incorporated into the contest, but the remaining judging classes/scenarios have been developed using PowerPoint software with videos, photos, graphs, and text information about the management of different animal species (Heleski et al., 2003). This contest has identified that animal welfare is laden with both science and ethics, hence the title of the contest: "Intercollegiate Animal Welfare Judging/Assessment Contest." *Assessment* refers to making objective and quantifiable evaluation of animal welfare, while *judging* refers to the ethics-based choice of what is deemed acceptable animal welfare (Heleski et al., 2003). By incorporating background information about animal welfare and ethics, norms for the species featured at the competition that year, and current scientific literature related to the topic, and applying this information to specific problems, students improve retention of information and take ownership in the learning process (Mench, 2008).

The contest initially included only undergraduate students, though it has now grown to include graduate and veterinary students. The veterinary division was added in 2008 with support from the AVMA (AVMA, 2016). The veterinary division has now become the largest segment of the contest, indicating an increasing interest in animal welfare education in veterinary students (Nolen, 2013). In the first contest in 2002, 18 undergraduate students participated; in

2014, 28 teams comprised of 116 individuals participated in the contest. According to Zanella, one of the contest's founders, this framework has "revolutionized teaching of animal welfare at many institutions" (Zanella, 2008).

WELFARE OF DAIRY HEIFER CALVES

The general public is showing increasing interest in how dairy cattle are raised, representing a growing concern for dairy cattle welfare. A recent online survey asking participants to describe the ideal dairy found that animal welfare concerns were the primary concerns, including painful procedures, humane treatment, and the ability to perform natural behaviors (Cardoso et al., 2016). Another study found that people with no relation to the dairy industry were less likely to agree with the practice of early separation of the calf from its dam compared with people in the dairy industry (Ventura et al., 2013). Interestingly, many of the reasons both for and against early calf separation were the same, identifying potential areas for public outreach. As people around the world are turning to legislation to mandate animal welfare, it is important for different stakeholders to find areas of agreement to put into policy. A study evaluating dairy industry stakeholders on their primary concerns helped to identify some of those areas of agreement, particularly related to animal welfare (Ventura et al., 2014).

As public concern for animal welfare increases, there becomes a greater need for understanding areas of increased risk for poor welfare. Dairy heifer calves represent the next generation of milk-producing animals on a dairy operation, and the preweaning phase represents a critical time period in the life of a dairy heifer. A survey of 115 dairy operations in Quebec, Canada, by Vasseur et al. (2010) identified seven risk areas to dairy heifer welfare. First, many operations did not have a dedicated calving pen, and many calvings were unattended, putting calves at risk of disease transmission or complications due to dystocia. Second, some farms

were not routinely disinfecting calves' navels and not identifying calves early. Third, colostrum management programs had many issues, including allowing calves to suckle, not feeding an appropriate volume, not testing the colostrum quality, and not monitoring passive transfer status in calves. Fourth, painful procedures such as dehorning and removal of extra teats were performed on older calves and without pain relief. Fifth, many calves were fed a restricted liquid diet. Sixth, many operations were weaning calves based on age rather than starter consumption. Seventh, calf housing was inappropriate on many operations. The survey influenced the design of an advisory tool addressing dairy heifer welfare that was tested on 28 Quebec dairy operations (Vasseur et al., 2010b). Overall the advisory tool was a reliable way to assess the welfare of dairy heifer calves, and it provided an educational opportunity to teach producers better ways of managing calves for better welfare outcomes.

A similar survey by Fulwider et al. (2008) on 113 dairy operations in the United States identified management practices related to dairy cattle welfare. Specific to dairy heifers, areas of concern included colostrum management practices, dehorning age and methods, and the lack of analgesic/anesthetic use for painful procedures. Stull and Reynolds (2008) focused on environment and housing, handling, transportation, nutrition and feeding, health, behaviors and physiology associated with pain, and euthanasia as important factors related to calf welfare. Many of these areas will be explored further in later sections of this review.

Another area of concern for dairy heifer welfare relates to unnatural feeding programs utilized on many operations. Feeding restricted amounts of milk or milk replacer in only a few meals per day, and frequently in a bucket, differs greatly from the natural feeding behaviors of beef counterparts reared with their dam (von Keyserlingk et al., 2009). By studying natural

feeding behaviors in calves, better feeding designs such as ad libitum automatic nipple feeders have been developed and fine-tuned to better meet the needs of dairy calves.

Indicators of animal welfare are important for identifying areas of concern and creating solutions. Production is often used as an indicator of animal welfare in mature animals (i.e. milk production, semen quality, and fertility). For dairy calves, growth, morbidity, and mortality are commonly used metrics to assess animal welfare (Hulbert and Moisá, 2016). Recently, measures of stress and immune function have been suggested as performance measures in dairy calves to assess animal welfare (Hulbert and Moisá, 2016). Continued research on how to assess the welfare of heifer calves is needed.

COLOSTRUM QUALITY AND PASSIVE TRANSFER IN DAIRY HEIFER CALVES

Dairy calves rely on passive transfer of immunity via colostrum for disease resistance. The placenta of the cow separates the blood supply of the dam and the calf during pregnancy, preventing the transfer of protective immunoglobulins in utero. Thus, calves are born agammaglobulinemic, and it takes several weeks for the calf's immune system to begin producing its own immunoglobulins (Gulliksen et al., 2008). Calves are dependent on consuming the immunoglobulin-rich colostrum within a short window after birth for adequate absorption of the immunoglobulins across the intestinal wall, defined as passive immunity. Immunoglobulins are the primary component of colostrum immunity enhancement, including IgG, IgA, and IgM, with IgG representing about 85% of the immunoglobulins in colostrum (Larson et al., 1980). An IgG concentration of greater than 50 g/L has been defined as high quality colostrum (McGuirk and Collins, 2004).

Colostrum also contains many other important constituents, including maternal leukocytes, growth factors, hormones, cytokines, nonspecific antimicrobial factors, and

important nutrients such as energy, protein, fat, vitamins, water, and minerals (Godden, 2008). Colostrum is an important heat source for neonatal calves, both in the form of energy from fat and lactose as well as a direct form of heat since it is fed at body temperature. Achieving adequate passive transfer of immunity not only reduces the risk of morbidity and mortality during the preweaning period (Nocek et al., 1984; Furman-Fratczak et al., 2011); long-term benefits include improved gains and feed efficiency, lower mortality in the postweaning period, reduced age at first calving, improved first and second lactation milk production, and lower risk of culling during the first lactation (Robison et al., 1988; DeNise et al., 1989; Wells et al., 1996; Faber et al., 2005). The four most important factors related to colostrum management for adequate passive transfer include quality, quantity, timing of feeding, and cleanliness (McGuirk and Collins, 2004).

The quality of colostrum is typically defined by the IgG concentration, with >50 g/L of IgG considered high quality colostrum (McGuirk and Collins, 2004; Godden, 2008). Colostrum quality can vary significantly from cow to cow; factors associated with colostrum quality include breed and age of the dam, vaccination program during pregnancy, and timing to collection of colostrum (Shearer et al., 1992; Gulliksen et al., 2008). Factors that are difficult to modify include cow age and breed. Differences among dairy breeds have been identified, with Holsteins producing the lowest quality colostrum and Jerseys producing the highest quality colostrum (Muller and Ellinger, 1981). Further research to determine whether these differences are due to genetics, or are a dilutional effect, has not been done at this time. Older dams generally produce higher quality colostrum, probably due to increased exposure to farm-specific pathogens (Muller and Ellinger, 1981). One study conducted by Tyler et al. found that third lactation Holstein dams produced the best quality colostrum, though no differences were detected between first and

second lactation Holstein dams (Tyler et al., 1999). Because of this, the common on-farm practice of discarding colostrum from first lactation heifers should be abandoned.

Another commonly held belief among dairy producers is that lower volumes of colostrum produced equate to higher quality colostrum, though research has not found a strong link between colostrum volume and IgG concentration (Maunsell et al., 1999). Dry period length does not seem to have an effect on colostrum quality (Shoshani et al., 2014; Mansfeld et al., 2015). Vaccines used during the preparturient period can increase colostrum quality as well as provide calves with protection for specific diseases of concern (Kehoe et al., 2007). Colostrum IgG concentration is highest immediately after calving, then drops off over time. Therefore, it is important to collect colostrum as soon after birth as possible (Moore et al., 2005). Pooling colostrum from multiple cows is a practice used on some dairy operations, though it is not recommended since high quality colostrum will be diluted by lower quality colostrum, and more calves could potentially be exposed to pathogens from colostrum (Weaver et al., 2000).

There are several methods available for measuring colostrum quality. Colostrum can be assessed visually for color and consistency, and colostrum with traces of blood should not be fed to calves (BAMN, 2001). However, visual appearance does not provide a good indication of IgG concentration in the colostrum, and additional testing should be done. A colostrometer, which is a type of hydrometer, measures the specific gravity of colostrum, providing an estimate of the IgG concentration using colored bands, with green indicating >50 g/L IgG, yellow indicating 20-50 g/L IgG, and red indicating <20 g/L IgG (Heinrichs and Jones, 2011). The measure is not always accurate, since the specific gravity can be influenced by the temperature of the colostrum as well as other colostral components, such as fat and other solids (Weaver et al., 2000). Additionally, the colostrometer is made of glass, making it a fragile instrument to use on farm.

The Brix refractometer measures the amount of sucrose in a solution, though it can be used to estimate colostrum IgG (Quigley et al., 2013). A Brix reading of 22% correlates with an IgG concentration of 50 g/L(Bielmann et al., 2010). Brix refractometers are available in both digital and optical models, and they are becoming a useful on-farm tool to assess colostrum quality. Radial immunodiffusion assays are considered the gold standard for measuring colostrum IgG concentration, though not a practical on-farm tool due to the cost and time it takes to run the assay, making it more useful for research purposes (Fleenor and Stott, 1981).

To ensure adequate passive transfer of immunity, calves must consume at least 100 g of IgG in the first feeding of colostrum (Weaver et al., 2000). This can be accomplished by feeding a higher quality of colostrum, a larger volume of colostrum, or both. The general recommendation is to feed at least 10% of body weight of colostrum at the first feeding, which equates to about 4 L for the average size calf (Godden, 2008). The absorption of colostrum by the calf can only occur during a short window of time. A calf's enterocytes have the ability to nonselectively absorb large molecules, including IgG, by pinocytosis, where they are then transported across the cell and deposited into the lymphatic system via exocytosis (Godden, 2008). The molecules are then absorbed into the bloodstream via the thoracic duct. This process decreases linearly from the time of birth until "gut closure" at approximately 24 hours of age. Because of this, the timing of colostrum feeding is the most important factor for efficient absorption of IgG. Current recommendations are to feed colostrum as soon as possible after birth, and always within the first four hours of life (Michanek et al., 1989; BAMN, 2001).

Bacterial contamination of colostrum can interfere with the absorption of immunoglobulins, potentially contributing to failure of passive transfer and/or exposing the neonatal calf to pathogens (Stewart et al., 2005). Blocking immunoglobulin uptake is presumed

to occur through two different methods. One, colostral IgG in the intestinal lumen will bind to bacteria, resulting in less IgG available for absorption by the calf. Two, bacterial cells will compete with the IgG molecules at the enterocyte receptors, resulting in decreased absorption (Godden, 2008). Colostrum should contain less than 100,000 cfu/ml total bacterial count and less than 10,000 cfu/ml total coliform count (McGuirk and Collins, 2004). A study in 2012 found that 43% of colostrum samples tested had total plate counts >100,000 cfu/ml, and only 39.4% of samples met industry standards for total plate counts and IgG concentrations (Morrill et al., 2012). Methods to prevent bacterial contamination of colostrum include not using colostrum from infected dams and not pooling colostrum, as well as using clean equipment for the collection, storage, and feeding of colostrum (Stewart et al., 2005). Colostrum storage, if done improperly, can allow for bacterial replication. If not fed immediately, colostrum should be frozen for storage, as refrigeration still allows for bacterial replication (Morrill et al., 2012). Heat treatment is a tool to help reduce the bacterial load, though it needs to be done at a lower temperature (60ºC) compared with milk pasteurization to avoid immunoglobulin protein denaturation (Godden, 2008; Armengol and Fraile, 2016). Heat treatment of colostrum can reduce the bacterial loads and improve IgG absorption (Johnson et al., 2007).

Measuring passive transfer of immunity in calves can help identify weaknesses in a colostrum management program. As with colostrum, the gold standard for measuring serum IgG concentration is radial immunodiffusion assays (Ameri and Wilkerson, 2008). A Brix refractometer can also be used to test serum IgG concentration, with a value of <8.4% associated with failure of passive transfer (FPT) (Deelen et al., 2014). A refractometer can be used to assess serum total protein, providing an indication of passive transfer since immunoglobulins are correlated with the total protein in the blood, with a value of <5.2 g/dL correlated with FPT

(Calloway et al., 2002). Serum samples should be tested between 24 hours and 7 days of age since serum immunoglobulins decrease during the first month of life (Tóthová et al., 2015). Calves with serum IgG levels below 10 g/L are considered to have FPT, and calves with serum IgG levels above 15 g/L are considered to have excellent passive transfer of immunity (Godden, 2008).

Researchers have understood the importance of colostrum for over 100 years (Crowther and Raistrick, 1916), yet in 2007, 19.2% of calves in the United States still had failure of passive transfer (Beam et al., 2009). This was a significant improvement from the 1991-1992 National Dairy Heifer Evaluation Project, in which more than 40% of calves had FPT (USDA, 1993). Colostrum quality has also improved over time. One study in 1992 found that 93.3% of colostrum samples had IgG levels below 50 g/L (Shearer et al., 1992). In 2012, the mean colostrum IgG was found to be 68.8 g/L (Morrill et al., 2012). Due to the importance of a good colostrum management program, this area has been a target for producer education programs over the past several decades (BAMN, 2001).

If high quality colostrum is unavailable to feed a calf, or if trying to minimize disease transmission to a calf via colostrum, colostrum replacers and colostrum supplements are available with powdered bovine immunoglobulins. These products will not have immunoglobulins for the specific pathogens found on that farm, making them useful only as a last resort. Colostrum supplements contain less than 50 g IgG per dose and little to no other nutrients, as they are designed to supplement natural colostrum (Godden, 2008). Colostrum replacers are more expensive, and the quality of colostrum replacers commercially available varies greatly (Quigley et al., 2001). Absorption of IgG from colostrum replacers has been shown to be lower than natural colostrum (Garry et al., 1996; Quigley et al., 2002). Feeding

colostrum replacers should be avoided, as the risk of FPT is increased when using these products.

Environmental factors associated with colostrum quality and passive transfer status have gained attention recently. One study found that colostrum IgG was positively correlated with the number of days above the thermoneutral zone during the dry period (Cabral et al., 2016). Another study found that the highest quality colostrum was produced at the end of summer and early fall in Norway (Gulliksen et al., 2008). Colostrum development begins during the dry period in the weeks prior to calving, so environmental factors would have the greatest influence on colostrum quality during the month prior to calving (Godden, 2008). Cold stress in the neonatal calf could potentially interfere with colostrum absorption (Olson et al., 1981). Thermal stress in general has been shown to negatively impact the absorption of colostrum IgG (Stott et al., 1976). Further research into the influence of environmental factors on the production and absorption of colostrum is needed, with particular attention on possible mitigation strategies.

AVERAGE DAILY GAIN IN DAIRY HEIFER CALVES

In the life of a dairy heifer calf, the preweaning period is a critical phase, and optimal conditions can set a calf up for success as a lactating cow. The age at first breeding and weight at first calving are determined by growth, and growth is associated with lifetime productivity (Heinrichs, 1993). Many different factors influence growth during the preweaning period, including passive transfer of immunity, disease, nutrition, management factors, and environmental factors (Place et al., 1998). Average daily gain (ADG) is one method of measuring growth during the preweaning period, as the length of the preweaning period varies greatly from operation to operation, and even among calves on the same operation. ADG can

provide an overall reflection of the preweaning period, and is a useful indicator of dairy heifer calf management.

While many different factors are associated with growth, nutrition is the most important determinants of growth. Additionally, nutrition is essential for the development of a healthy rumen. When calves are born, they are essentially monogastric animals, and all nutrients come exclusively from the liquid milk diet (Drackley, 2008). Calf starter is recommended to first be offered to calves by 4 days of age, though they will not consume much until about 3 weeks of age (BAMN, 2003). By this age, calves should be consuming enough starter to stimulate rumen development. Consuming starter results in microbial fermentation of the carbohydrates into volatile fatty acids. The rumen epithelium is stimulated to differentiate into papillae by butyric and propionic acids (Heinrichs et al., 2005). Calves need to have clean water available (in liquid form; separate from the milk diet) to stimulate starter intake (Kertz et al., 1984; BAMN, 2003). Calves are the most efficient at growth during the preweaning period, with growth efficiency declining steadily as they get older (Owens et al., 1993; Kertz et al., 1998). Growth during the preweaning period primarily occurs in the form of skeletal and muscular growth (Drackley, 2008). Therefore, growth should be maximized during the preweaning period.

In an attempt to improve starter intakes in order to wean calves early from a liquid milk diet, many dairy operations began limit feeding the liquid diet to calves. While this did accomplish the goal of increasing starter intake, it sometimes did so at the expense of growth and overall health (Flower and Weary, 2001). A typical calf feeding protocol included two feedings per day of 8-10% of body weight fed daily, which is equivalent to about 2 L twice per day (Thickett et al., 1986). Enhanced feeding programs have gained popularity recently, typically feeding a milk replacer with a higher percent protein or feeding milk ad libitum using an

automated calf feeding system, providing a more natural approach to calf feeding (Jasper and Weary, 2002; Terré et al., 2009). One study found that calves fed ad libitum milk consumed twice as much milk and gained four times as much compared with restricted-fed calves, and the restricted fed calves displayed signs of hunger during the study (De Paula Vieira et al., 2008). Another study found that calves fed ad libitum milk would consume 16-20% of body weight (Hafez and Lineweaver, 2010). Calves fed ad libitum milk had significantly higher ADG and more normal feeding behaviors compared with calves limit-fed milk (Appleby et al., 2001). Greater milk consumption during the preweaning period leads to increased gain, improved feed efficiency, reduced incidence of disease, and greater opportunities to express normal behaviors (Khan et al., 2011).

Ultimately, both the quantity and the quality of the liquid diet impact dairy heifer growth and health (Drackley, 2008). The rate-limiting nutrient for calf growth during this period is protein, with protein requirements determined by the desired rate of gain (Drackley, 2008). Protein is required in the diet to provide essential amino acids needed for growth. Increasing the protein in the diet appeared to have a positive linear relationship with growth (Blome et al., 2003). Another study showed that calves fed a high protein diet had greater ADG than calves fed mid or low protein diets (Diao et al., 2008). While amount of protein has a strong correlation with ADG, the protein source does not appear to significantly influence growth (Terosky et al., 1997). The NRC requirements for calves (NRC, 2001) state that for an average size calf (45 kg) under thermoneutral conditions, the metabolizable energy required for maintenance is 1.75 Mcal/day. This is equivalent to about 2.5 L of whole milk, or about 3.0 L of an average milk replacer just to meet the daily maintenance requirements in the thermoneutral zone, without

considering the energetic needs for growth or the increased energetic demands of stress (Drackley, 2008).

Improved nutrition during the preweaning phase can also positively influence a calf's overall immune function. While intuitively it makes sense that if calves are provided an appropriate diet and are growing then they must be healthy, very few studies evaluating the influence of nutrition on disease resistance have been done until recently. Most studies have focused on the inclusion of coccidiostats or antibiotics in the diet on calf health, but not the actual nutrition provided by the diet. Research has shown that calves fed less energy and protein than necessary for growth also had higher mortality (Goff, 2006). One study conducted via ex vivo cell function assays found that the plane of nutrition may modulate functions associated with cell mediated immunity (Nonnecke et al., 2003). In a controlled trial comparing a low plane of nutrition with a high plane of nutrition during the preweaning period, as well as *Mannheimia haemolytica* dose, on responses to a combined bovine herpesvirus-1 and *Mannheimia haemolytica* challenge post weaning, calves fed a low plane of nutrition preweaning responded more severely to the combined viral and bacterial challenge postweaning (Sharon et al., 2015a; Sharon et al., 2015b). These studies showed that early life nutrition can influence resistance and pathology of disease, since feeding a lower plane of nutrition during the preweaning period appeared to increase the risk of respiratory disease one month after weaning. In another study, calves fed a high plane of nutrition during the preweaning period had a greater acute phase response to an opportunistic bacterial enteric infection compared with calves fed a low plane of nutrition (Liang et al., 2015). By feeding calves better during the preweaning period, there appears to be added benefits to immune function as well as better growth rates. Disease during the preweaning period negatively impacts growth since vital nutrients from the

diet are lost via diarrhea, energy is diverted away from growth, appetite is suppressed and feed intake decreased (Virtala et al., 1996; Donovan et al., 1998). Preventing disease during the preweaning period is critical, and includes a proper colostrum management program, housing calves in a clean and comfortable environment, and providing calves with proper nutrition (LeBlanc et al., 2006).

Giardia and *Cryptosporidium* are two common intestinal parasites in dairy calves that can cause diarrhea, and both are zoonotic pathogens. Both are endemic in US dairy herds, with no available treatments other than supportive care (Garber et al., 1994). Prevention is key, making hygienic practices on farm essential. *Cryptosporidium* causes diarrhea in calves from decreased absorptive capacity and osmotic diarrhea due to damage to the brush border of enterocytes (Constable, 2014). *Cryptosporidium* infections generally occur early in the preweaning period, between 1-3 weeks of age (O'Handley et al., 1999; Santín et al., 2004). *Giardia* infections generally occur a bit later, around 4 weeks of age, and cause calves to have diarrhea or failure to thrive (Olson et al., 1997; O'Handley et al., 1999).

Calf comfort can sometimes be overlooked as a factor related to calf growth, though providing calves with a comfortable environment encourages calves to spend more time lying down, thus improving their growth. This was shown in a study by Mogensen et al., in which calves with more lying bouts tended to have higher gains compared to calves with fewer lying bouts (Mogensen et al., 1997). Bedding and housing can help mitigate the negative effects of environmental factors on growth, such as thermal stress. Calves with a deep layer of straw are able to bed down and thermoregulate better in cold temperatures, while sand bedding helps cool calves during hot temperatures. Several studies have shown that calves prefer sawdust over other bedding types (Camiloti et al., 2012; Worth et al., 2015). Calves bedded with straw gained

more than calves bedded with sand in one study (Hill et al., 2011). Bedding can also influence disease, as shown by Panivivat et al., in which calves bedded with sand had more scour treatments and scored the dirtiest compared with all other bedding types (Panivivat et al., 2004) While there are various different types of calf housing options available, all should provide calves with shade during hot temperatures, a block from the wind, and a covering from precipitation. Calves are typically housed individually to help reduce the spread of disease, though different studies have reached different conclusions about what housing system results in better growth (Quigley et al., 1995; Hill et al., 2011). Group housing of calves is becoming more common on dairy operations. The most important thing is to provide calves with a clean and comfortable environment, which will vary depending on the individual farm factors.

Environmental factors during the preweaning period can influence overall calf growth. Thermal stress results when there is any deviation from the thermoneutral zone for a calf (Roland et al., 2016), and maintenance requirements increase (Drackley, 2008). Calves that experience heat stress during the preweaning period have lower starter consumption rates and lower body weights at weaning, indicating that heat stress negatively impacts growth (Broucek et al., 2009). Decreased feed intake during periods of heat stress have been shown to be caused by decreased blood flow to the digestive tract, leading to decreased absorption of nutrients (Beede and Collier, 1986). Cold stress has the opposite effect, with cold temperatures driving appetite up. The volume of liquid milk fed to calves during periods of extreme cold should be increased, though calves can help meet their maintenance requirements by increasing starter consumption. One study found that calves raised in a cold environment had similar gains to calves raised in a warm environment, yet the calves in the cold environment consumed more starter (Nonnecke et al., 2003). Another study showed that calves raised during the winter gained the most, whereas

calves raised during the summer gained the least when comparing ADG across seasons (Place et al., 1998). Housing, bedding, nutrition, and the environment are all interconnected, and all can influence calf growth.

Interestingly, the environmental factors during the dam's dry period can influence calf growth. The dry period generally represents the last few weeks of pregnancy, during which the calf experiences significant growth, with about 75% of the total weight gain occurring in the last trimester. A recent study found that calves born from cows that were cooled during periods of heat stress in the dry period had higher birth weights compared with calves from dams that were not cooled, and those bigger calves continued to have better growth after birth (Dahl et al., 2016). This is potentially due to reduced dry matter intake during periods of heat stress in the cow, which negatively impacts placental development (Dahl et al., 2016). Additionally, there appear to be direct effects on calves that experience heat stress in utero. Calves that were heat stressed in utero had permanent metabolic shifts associated with greater fat accumulation and less lean growth (Tao and Dahl, 2013). Similarly, calves that were not heat stressed in utero consumed more starter and gained more during the preweaning period compared with calves that were heat stressed in utero (Monteiro et al., 2016). The importance of mitigating heat stress in lactating cows is well documented, though the importance for dry cows has implications beyond just the dams, and could have direct implications on the growth of the unborn calf.

Other factors associated with growth during the preweaning period include the number of calves born and the dam lactation. This is probably due to the effects on birth weight, as birth weight has been shown to be a predictor for calf growth (Lundborg et al., 2003). Twin calves tend to have significantly lower birth weights than single calves (Kertz et al., 1998; Hossein-Zadeh, 2010). While ADG accounts for birth weight in the equation, it appears that twin calves

are not able to catch up in growth during the preweaning period. In beef cattle, twin calves have lower birth weights and lower gains than single calves (Gregory et al., 1996). Birth weight is also positively associated with parity (Linden et al., 2009), and larger cows tend to have larger calves (Swali and Wathes, 2006). During their first lactation, heifers are still growing, resulting in smaller calves at birth (Losinger and Heinrichs, 1997). It is important to note that as calf size at birth increases, so does the risk for dystocia (Lombard et al., 2007).

Many factors influence the growth of preweaned dairy heifers, including nutrition, disease, immune function, birth weight, environmental factors, and others. By monitoring ADG in preweaning calves on a dairy operation, any deviations from the operation average can provide a warning sign, and further investigations can be made to identify the problem. Measuring calf growth is another useful tool for dairy producers to perform in order to monitor the overall calf management program.

DAIRY BULL CALVES

Since dairy bull calves can never produce milk, they are often seen as a byproduct of the dairy industry. Because of this, there is a potential for dairy operations to place a greater emphasis on the overall care and management of dairy heifer calves than bull calves. Perhaps related to this, there exist very few scientific research studies focusing on the care and management specifically of dairy bull calves, but all of the principles for dairy heifer calves hold true for bull calves.

As with heifer calves, proper colostrum management is one of the most important factors for the overall health and welfare of dairy bull calves. Since calves are born agammaglobulinemic, colostrum is critical for calves to resist infection during the first few weeks of life (Gulliksen et al., 2008). Bull calves are particularly at risk of exposure to disease

early in life since they are commonly sold from the operation of origin and comingled with calves from other operations. Additionally, these young calves are subjected to the stress of handling and transport at a very young age, making passive transfer of immunity critical for protecting them from diseases. One study found that veal calves were at a high risk for failure of passive transfer of immunity, with 78% of calves in veal facilities having inadequate immunity (Stull and McDonough, 1994). Further research regarding colostrum management practices of bull calves is needed.

Dehorning is commonly performed on dairy calves to reduce the risk of injuries to handlers and other cattle. While most dairy calves are dehorned, this practice is especially important for bull calves raised for meat due to the significant hide damage and carcass losses that can be attributed to bruising from horns (Marshall, 1977). That being said, dehorning does still cause a significant amount of pain and stress to calves. When ranked according to stress, cautery disbudding was the least stressful, followed by caustic disbudding, and most stressful was amputation dehorning (K.J. Stafford and Mellor, 2005). All dehorning procedures were considered less stressful if anesthetic and/or analgesic techniques were used, including sedation, local anesthesia, and non-steroidal anti-inflammatory drugs (NSAIDs) (Graf and Senn, 1999; K.J. Stafford and Mellor, 2005). Calves should be dehorned as young as possible to lessen the amount of pain experienced by the calves, and some believe the age of dehorning is more important than the method used (Stookey, 1994). In some countries, there is now legislation mandating the use of pain mitigation techniques for painful procedures, and currently there are options to control acute and chronic stress associated with dehorning (Stock et al., 2013). Calves that are dehorned with local anesthetics are much easier to work with since they struggle less

during the dehorning procedure, creating an added benefit to using pain relief (Grondahl-Nielsen et al., 1999).

Castration is commonly performed on bull calves to reduce unwanted behaviors and improve carcass quality. All physical methods of castration cause pain (K. Stafford and Mellor, 2005). Recently the public has become more concerned about causing pain in animals, including castration in cattle (Weary and Fraser, 2008), leading to many studies investigating different castration techniques and pain mitigation strategies. All castration methods cause acute pain, though banding causes cattle the most chronic pain (Robertson et al., 1994; Molony et al., 1995). This pain has been associated with decreased growth and can negatively impact average daily gain (Fisher, 1996). The AVMA recommends using pain relief for all castration methods (AVMA, 2014). Acute distress due to castration can be alleviated with local anesthetics, but to truly address the pain and stress of the procedure, a multimodal approach is needed, including local anesthetics for acute pain and NSAIDs for chronic pain (Coetzee, 2011; Coetzee, 2013).

Further investigation into the management of dairy bull calves is needed to identify risk factors for poor calf welfare. Studies evaluating colostrum management programs and resulting passive transfer of immunity in bull calves are warranted. Additionally, painful procedures are gaining attention in the general public, and significant amounts of research have been done evaluating the best methods to reduce pain associated with dehorning and castration. What is not currently known is how many operations have adopted these practices.

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CHAPTER III: SURVEY OF ANIMAL WELFARE, ANIMAL BEHAVIOR, AND ANIMAL ETHICS COURSES IN THE CURRICULA OF AVMA COUNCIL OF EDUCATION–ACCREDITED VETERINARY COLLEGES AND SCHOOLS[1]

INTRODUCTION

Animal welfare, animal behavior, and animal ethics are topics of increasing importance to the general public. Many animal owners expect veterinarians to be experts on animal behavior, management, and welfare. Over the past few decades, a changing social ethic has resulted in the public having greater moral concern for animals (Rollin, 1994). Growing concern for animal welfare has led to increased consumer demand for humanely produced products worldwide (Fraser, 2008a). Animal welfare issues are complex and involve scientific, ethical, political, and economic factors (Lund et al., 2006). An understanding of basic animal welfare is necessary for veterinarians to help them advise clients and be meaningfully involved in animal welfare issues and explain those issues to the public.

Animal behavioral issues are commonly seen in veterinary practice. Causes and treatment of behavioral problems can be complex (Turner, 1997). Dogs with behavioral problems are more likely to be relinquished to a shelter than are dogs without behavioral problems (Patronek et al., 1996). Investigators of 1 study found that behavioral problems were the number one reason provided by owners for the relinquishment of dogs and the number two reason for the relinquishment of cats (Salman et al., 2000). In another survey, 39 of 80 (48%)

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people who had relinquished their dogs indicated that problem behaviors strongly influenced that decision (Kwan and Bain, 2013). Horse owners also seek veterinary guidance for solving behavioral problems, such as cribbing, weaving, and pawing (Luescher et al., 2010). Additionally, animal behavior is one of the primary measures used to assess animal welfare (Fraser, 2008b). Often the first indication of illness is a change in behavior, which makes understanding animal behavior crucial for all veterinarians. For veterinarians to address complex behavioral issues, animal behavior must be understood and should be included in the veterinary curriculum.

A basic understanding of animal ethics is essential for making decisions about animal care and use. Veterinary medicine is a high-stress profession, and learning how to use a moral compass to make difficult decisions can help alleviate some of that stress (Gray, 2014). Veterinarians are often most comfortable when working within an objective scientific framework, but successfully dealing with difficult issues may require thinking and working within different ethical frameworks (Gray, 2014). In Europe, the approach to teaching veterinary ethics varies greatly among veterinary schools (Magalhães-Sant'Ana, 2014). The same is true among US veterinary schools. However, the public consistently ranks veterinarians among the most honest and ethical professionals (Gallup Poll, 2014). To meet the demands of the profession and maintain positive public opinion, veterinarians need education on ethical principles.

On the basis of public demand and professional obligations for veterinarians, all veterinary students should be taught animal welfare, behavior, and ethics in the core curriculum. The objective of the study reported here was to explore the extent to which veterinary colleges

and schools accredited by the AVMA COE have incorporated specific courses related to animal welfare, behavior, and ethics.

MATERIALS AND METHODS

Survey of AVMA COE–accredited veterinary schools (part 1)

A survey (**Online supplement** available at http://avmajournals.avma.org) was constructed with 23 questions. Three questions were devoted to identification of the institution and a contact person should additional clarification of any answers be needed. There were 18 multiple-choice questions; 9 focused on animal welfare, 6 focused on animal behavior, and 3 focused on animal ethics. The remaining 2 questions were open ended and requested comments about the inclusion of those 3 focus areas (animal welfare, behavior, and ethics) in the curriculum and about the survey. For each focus area, questions asked specifics about course structure (i.e., whether a formal course existed, course name, was the course required or elective, number of credits, when the course was offered during the program, and format of the class). Several questions asked about the inclusion of specific topics in the formal courses currently being offered. If no formal course was offered in any of the 3 focus areas, a question was asked about where in the curriculum that material was addressed.

The survey was approved by the Colorado State University Institutional Review Board and the American Association of Veterinary Medical Colleges. The survey was e-mailed to the associate dean of academic affairs at all 49 AVMA COE–accredited collages and schools of veterinary medicine in October 2014 requesting a response within 2 weeks. One reminder was e-mailed approximately 5 days before the response deadline.

Review of curricula from all 30 AVMA COE–accredited veterinary colleges and schools in the United States (part 2)

After the survey of part 1 was administered, all 30 AVMA COE-accredited colleges and schools of veterinary medicine in the United States were contacted for copies of the current curriculum. Copies of the curricula were collected during the spring of 2015 from the associate dean of academic affairs or from publicly available institution websites. Each curriculum was reviewed for courses relating to animal welfare or wellbeing, animal behavior, and animal ethics. Courses were or were not categorized into 1 of the 3 focus areas (animal welfare, animal behavior, or animal ethics) primarily on the basis of course titles and descriptions (when available). For courses to be categorized in the animal welfare area, the term welfare or wellbeing had to be included in the course title. For courses to be categorized in the animal behavior area, the term behavior, behavioral, or ethology had to be included in the course title. For courses to be categorized in the animal ethics area, the term ethics or ethical had to be included in the course title. Courses within the 3 focus areas were further categorized as elective or required and by year of the professional program during which they were offered (when available).

Data analysis

For the survey of part 1, descriptive statistics were generated for each survey response, and responses for US and international institutions were noted. For the curricula review of part 2, descriptive statistics were created. For the institutions that participated in both parts of the study, an attempt was made to validate the self-reported survey results from part 1 by comparing those survey results with the curricula review results of part 2.

RESULTS

Survey (part 1)

Of the 49 AVMA COE–accredited institutions surveyed, 10 of 30 (33%) US institutions and 7 of 19 (37%) international institutions responded. The 7 international institutions that responded were located in Europe (n = 3), Canada (2), Australia (1), and Mexico (1).

Six of the 7 international institutions and 4 of the 10 US institutions that responded indicated that they offered a formal course in animal welfare. The animal welfare course was required at 9 of those institutions and an elective at 1 US institution. Five of the formal animal welfare courses consisted of lecture only, whereas the remaining 5 courses consisted of lecture with some laboratory time. Four of the responding institutions offered > 1 course related to animal welfare. At 9 of the 10 responding institutions, the formal animal welfare course was offered during the first 2 years of the veterinary curriculum, whereas 3 responding institutions offered animal welfare courses during the final 2 years of the veterinary curriculum.

Topics most commonly covered in the formal animal welfare courses included general animal welfare principles (n = 9), companion animal welfare issues (10), equine welfare issues (8), and livestock welfare issues (10). Other topics covered in some courses were laboratory animal welfare, international and cultural differences in animal welfare, euthanasia, zoo and wildlife welfare, and animals in captivity. Seven of the 10 responding institutions had ≤ 1 full-time–equivalent faculty or staff devoted to teaching animal welfare, with 3 of those institutions having < 0.25 full-time–equivalent faculty or staff devoted to teaching animal welfare.

Of the 7 institutions that did not currently offer a formal course in animal welfare, 2 planned to add a course in the next 5 years, 1 did not plan to add a course, and the remaining 4 were unsure if they would add an animal welfare course to their curricula. All 7 of the

institutions without a formal animal welfare course stated that general animal welfare principles were covered somewhere in the curriculum, and 6 of the 7 institutions reported that other coursework covered companion animal welfare issues, equine welfare issues, and livestock welfare issues.

When the 17 responding institutions were asked to indicate their extent of agreement with the statement, "The animal welfare training in our current curriculum adequately addresses the public demand for veterinarians to be knowledgeable of this subject", all 7 international institutions and 3 of 10 US institutions responded with strongly agree or agree and the remaining 7 US institutions responded with neutral or disagree.

Nine of the 17 responding institutions reported that they offered a formal course on animal behavior, and 5 other institutions reported that they offered a combined course on animal behavior, welfare, and ethics. The animal behavior course was required at all but 1 of those institutions. Of the 14 (6 international and 8 US) institutions with a formal animal behavior course, the format for that course was primarily lecture with some laboratory time at 9, lecture only at 4, and primarily laboratory time with some lecture at 1. Thirteen of the 14 institutions offered an animal behavior course during the first 2 years of the veterinary curriculum, and some institutions offered multiple animal behavior courses. Topics covered in the formal animal behavior courses included companion animal behavior (n = 13), equine behavior (12), and livestock behavior (11). Other topics covered in the animal behavior courses at some institutions were exotic and wildlife behavior, laboratory animal behavior, and learning theory. The 3 institutions that did not offer a formal animal behavior course reported that the topics of companion animal, equine, and livestock behavior were covered in other courses.

Of the 17 responding institutions, 5 of 7 international institutions and 3 of 10 US institutions reported that they had a formal course on animal ethics. The 9 institutions that did not have a formal animal ethics course reported that animal ethics were addressed in other courses. Four of those institutions sponsored animal ethics experts to speak on campus with a frequency of 2 to many times per year, and veterinary students were required to attend most of those sponsored lectures.

Nine institutions provided a response to the following survey query: "We welcome your comments about the inclusion of animal welfare, behavior or ethics in the professional curriculum." Those responses included, "it is vital", "it is fundamental for veterinary professionals", "veterinary medicine is more than the physical health of the animal and should include teaching these topics", and "it should be a core part of the curriculum"; the remaining 5 responses clarified answers provided to previous questions.

Curriculum review (part 2)

Of the 30 AVMA COE–accredited veterinary colleges and schools in the United States, only 4 provided us with copies of their curricula; the curricula for the remaining 26 institutions were obtained online. Thus, the curricula for all 30 AVMA COE–accredited US institutions were reviewed.

Six of 30 (20%) institutions provided a formal course with the term animal welfare or animal wellbeing in the title. The course was required at all 6 of those institutions, and 1 institution also offered an elective course on animal welfare. All courses were 1 to 2 credits. The year of the veterinary curriculum during which the required animal welfare course was provided varied among the 6 institutions.

Twenty-two of 30 (73%) institutions provided a formal course with the term animal behavior or ethology in the title. The course was required at 14 institutions, an elective at 7 institutions, and not specified as required or elective at 1 institution. Seven institutions offered an elective course on animal behavior in addition to the required course. The number of credits for the animal behavior course and the year of the veterinary curriculum during which it was offered varied among the institutions. Seven institutions had courses with the term small animal behavior or companion animal behavior in the course title.

Eighteen of 30 (60%) institutions provided a formal course with the term ethics in the title. The course title also included the term law or jurisprudence at 9 of those 18 institutions. The course was required at 17 institutions and an elective at 1 institution. The number of credits for the formal ethics courses ranged from 1 to 3. The year of the veterinary curriculum during which the ethics course was offered varied among institutions.

Comparison of survey responses (part 1) with results of curriculum review (part 2)

Ten US institutions were included in both part 1 and part 2. The results for part 1 were the same as those for part 2 for 5 of the 10 institutions. For 3 institutions, review of the curriculum revealed courses (3 animal ethics courses and 1 animal behavior course) that were not reported in the survey of part 1. Two institutions reported courses (1 animal welfare course and 1 animal behavior course) in part 1 that were not identified in the curriculum review of part 2.

DISCUSSION

Animal welfare, animal behavior, and animal ethics represent only 3 of the many subjects that must be covered in formal veterinary medical education, yet they encompass how and why we care for and use animals. There is a growing body of science surrounding those topics, and the AVMA recognizes 2 related board specialty colleges (American College of Animal Welfare

and American College of Veterinary Behaviorists). Veterinary students need to be properly trained on those subjects to meet the needs and expectations of society. Results of the present study provided preliminary information regarding the extent to which courses on animal welfare, behavior, and ethics are being offered in the curricula of AVMA COE–accredited colleges and schools of veterinary medicine.

Findings of the present study suggested that, of the areas assessed (animal welfare, behavior, and ethics), formal training on animal welfare was the area most frequently lacking in the curricula of many veterinary training programs. On the basis of responses to the survey of part 1, 6 of 10 US institutions and only 1 of 7 international institutions lacked a formal animal welfare course. The curricula review of part 2 revealed that only 6 of the 30 AVMA COE–accredited veterinary colleges and schools in the United States offered courses the included the term animal welfare in the title. Although the survey of part 1 had a low response rate, the posted curricula of all US veterinary colleges and schools were reviewed during part 2. We acknowledge that formal courses are not the only method for teaching animal welfare; however, it appeared that not all US institutions addressed animal welfare topics related to specific species, potentially resulting in students who were unaware or uninformed about animal welfare issues. There was a distinct difference in how international and US institutions responded to the statement, "The animal welfare training in our current curriculum adequately addresses the public demand for veterinarians to be knowledgeable of this subject." All 7 international institutions that responded either strongly agreed or agreed with that statement, whereas only 3 of 10 US institutions that responded either strongly agreed or agreed with that statement; the remaining 7 US institutions were either neutral or disagreed with that statement. Those responses were self-reported, with 1 international and 1 US institution strongly agreeing that

their curriculum was adequately addressing the public expectations for veterinarians' knowledge related to animal welfare despite the fact that a formal course on animal welfare was not provided. Unfortunately, there was no method to verify that the responding institutions were or were not meeting public expectations, or whether the person who completed the survey was fully aware of the depth and breadth of animal welfare science. Regardless of whether a formal animal welfare course was offered, the findings of the present study indicated a need to increase the amount of time dedicated to teaching veterinary students about animal welfare at US institutions.

In the survey of part 1, 9 of the 17 responding institutions offered a formal course dedicated to animal behavior, and another 5 institutions offered formal courses that combined animal behavior, ethics, and welfare. In part 2, review of the posted curricula for the 30 US veterinary training institutions revealed that 22 (73%) offered formal courses on animal behavior. Although most institutions offered courses dedicated to animal behavior, 7 had behavior courses with the term small animal or companion animal in the title, which suggested a potential need for courses that focus on the behavior of other species. Understanding the behavior of livestock species is an important aspect of animal welfare assessments, and is critical for ensuring the safety of both people and animals during the handling of those species. Additionally, a change in behavior is often the first indication of pain or disease in veterinary patients; therefore, all veterinary students need a basic understanding of animal behavior to address the needs of their future patients and clients.

The survey results of part 1 indicated that only 3 of 10 US institutions and 5 of 7 international institutions offered a formal course on animal ethics. The 9 responding institutions that did not offer a formal course on animal ethics stated that they addressed animal ethics in

other courses, and several brought in guest lecturers on the topic. The results of the curriculum review in part 2 indicated that 18 of 30 (60%) US institutions offered formal courses that included the term animal ethics in the title, and 9 of those courses also included the term law, legal, or jurisprudence in the title. Although it is important for veterinary students to learn about veterinary law, that differs from the general principles of animal ethics. Veterinarians need to be cognizant of various beliefs regarding animal use because they will likely encounter people with differing philosophical beliefs about the use of animals during their careers.

For the 10 US institutions that were evaluated in both parts 1 and 2 of the present study, the results of part 1 were identical to those of part 2 for 5. The 5 institutions that differed were more likely to underestimate rather than overestimate their courses during the survey. During the survey, 3 institutions failed to report courses that were identified during the curriculum review, whereas 2 institutions reported courses that were not found during the curriculum review. Three institutions reported that they did not offer a course on ethics, but review of the curriculum for each of those institutions revealed a course with the term ethics in the title. Discrepancies between the results of parts 1 and 2 for some institutions suggested that the posted curricula were not kept up to date, courses changed between the survey and the curriculum review, or the person completing the survey was unaware of all the courses offered at that institution. The 5 institutions that had discrepant results between parts 1 and 2 need to improve the publicizing of their curricula so that it can be better understood by both insiders and outsiders. Additionally, the discrepant findings between parts 1 and 2 highlighted important differences between self-perception or reporting and an external curriculum review.

In May 2012, the World Organisation for Animal Health published recommendations on competencies for graduating veterinarians (OIE, 2012). That document outlines the minimum

competencies all graduating veterinarians need to serve the public and stated that all of those competencies should be included in the veterinary curriculum. It states that, "veterinarians should be the leading advocates for the welfare of all animals" (OIE, 2012). Animal welfare is a core competency and includes explaining animal welfare and related responsibilities of animal caretakers, identifying animal welfare problems and helping to correct them, and knowing where to find current information on animal welfare standards for animal production, transport, slaughter, and death. Veterinary legislation and ethics is another core competency outlined in that document and includes understanding laws related to veterinary medicine, understanding and applying high standards of veterinary medical ethics, and serving as leaders in society on the use of animals. On the basis of that document, all veterinary colleges or schools should be training veterinarians to be leaders in animal welfare and ethics. Results of the present study indicated that not all veterinary colleges and schools are meeting that obligation.

In 2008, the American Association of Veterinary Medical Colleges created the NAVMEC to address the needs of a changing veterinary profession. The NAVMEC final report identified core competencies for graduate veterinarians that included leadership in animal welfare and ethical practice (NAVMEC, 2011). It also identified evolving societal needs and stated that veterinarians will be expected to take more of a leadership role on animal welfare issues. The NAVMEC report advised all veterinary colleges and schools in North America to include animal welfare in their curricula in addition to meeting the World Organisation for Animal Health recommendations for all veterinary training programs throughout the world. Several years have passed since the NAVMEC report was published, yet many US veterinary colleges and schools still do not offer courses on animal welfare.

The purpose of the present study was to review educational programs offered on animal behavior, ethics, and welfare by AVMA COE–accredited veterinary colleges and schools with a focus on formal courses related to those topics. Formal courses are certainly not the only acceptable method of preparing veterinary students to deal with animal welfare, behavior, or ethics. It could be argued that having a culture that focuses on animal welfare and incorporating animal welfare training into all courses would better educate students, compared with having 1 formal course on animal welfare during 4 years of training. For example, animal welfare could be included in a physiology course during discussion about stress and again in a nutrition class and revisited during case management in the clinical training phase. Incorporation of animal welfare material into the curriculum in various ways allows for repetition and increases the likelihood that veterinary students will master the subject matter by the time they graduate. There are many different methods of teaching, and as long as students learn the material, one method is not necessarily better than the other.

An advantage of formal courses is that they allow for transparency of what veterinary students are being taught. One of the authors (TG) is a particularly strong proponent of course transparency and believes that the inclusion of courses in the veterinary curriculum that contain the terms animal behavior and animal welfare in their titles assures the public that veterinarians are being trained in those areas. Additionally, transparent course titles allow students in preveterinary programs who have an interest in animal welfare, behavior, and ethics to compare curricula among veterinary colleges and schools and make informed decisions regarding the program that best suits their interests. Although there is a lot of information on animal welfare and ethics available, not all of it is from credible sources. Making it readily known that

veterinarians receive formal training on animal welfare, behavior, and ethics can help promote the positive public image of the profession.

Evaluation of veterinary curricula is challenging owing to the complexity of the curricula and the fairly small number of institutions with doctor of veterinary medicine degree programs. The survey of part 1 resulted in a lower than desired response rate (17/49 [35%); therefore, the curriculum review of part 2 was undertaken. The low response rate to the survey of part 1 might have been attributable to self-selection of institutions; some institutions that did not offer formal courses on animal welfare, behavior, and ethics may have been less inclined to respond to the survey than those that did offer courses on those topics. Only a limited amount of information could be obtained from review of the posted curricula because not all institutions provided course descriptions along with the course titles. Thus, the courses could only be assessed as posted; we could not assess other courses that might cover animal welfare, behavior, and ethics but for which information about the content of those courses was not provided.

The results of the present study cannot be used to assess how well educated and conversant veterinary graduates are in the areas of animal welfare, animal behavior, and animal ethics, but that is clearly the ultimate target for further research. All institutions with veterinary training programs should be assessing the level of understanding their students have in those areas. If veterinarians are going to fulfill their role as guardians of animal welfare and as providers of information, guidance, and advice to animal owners, producers, consumers, and policy developers, then they need to not only be aware of the issues, but also fluent in the language and conversant on methods to assess and monitor animal welfare, care, and behavior.

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CHAPTER IV: TEACHING TIP: TEACHING ANIMAL WELFARE VIA COMPETITIVE JUDGING CONTESTS

INTRODUCTION

In 2010, the AVMA added animal welfare to the veterinary oath, indicating that all veterinarians must be committed to protecting animal welfare (Nolen, 2011). Animal welfare is defined by the AVMA as how an animal is coping with the conditions in which it lives (AVMA, 2015). The scientific study of animal welfare involves complex assessments of an animal's physical health, emotional state, and the naturalness of its environment (Fraser et al., 1997). Animal welfare assessments must take each species' needs into consideration, and consider the societal and ethical framework for evaluation. These issues are complex, including factors related to science, ethics, politics, and economics (Lund et al., 2006).

According to Rollin, an animal ethicist at Colorado State University, the general public has increasingly shown moral concern for animals as a changing social ethic has evolved over the last several decades (Rollin, 1994). There has been an increased consumer demand for humanely raised animal products worldwide due to a growing concern for animal welfare (Fraser, 2008). The AVMA now recognizes a board specialty college in the field, the American College of Animal Welfare. Veterinarians work at the interface of all forms of animal use. Veterinarians need a basic understanding of animal welfare principles in order to be involved in solving animal welfare issues, advising clients, and educating the public.

In 2011, the North American Veterinary Medical Education Consortium (NAVMEC) report was published, identifying core competencies for graduate veterinarians, including leadership in animal welfare and ethical practice (Andrews, 2011). In 2012, the World

Organization for Animal Health (OIE) published recommendations for minimum competencies needed by all graduating veterinarians to meet the needs of the public (OIE, 2012). Animal welfare was identified as a core competency. Veterinarians should be competent at explaining animal welfare and related responsibilities of animal caretakers, identifying and helping correct animal welfare problems, and knowing where to find current information on animal welfare standards for animal production, transport, slaughter, and death (OIE, 2012). The report stated, "veterinarians should be the leading advocates for the welfare of all animals" (OIE, 2012). Yet a survey of all AVMA Council on Education accredited veterinary schools in the United States highlighted a need for more formal coursework on animal welfare (Shivley et al., 2016). The purpose of this paper is to provide an example of teaching animal welfare through competitive animal welfare judging contests.

COMPETITIVE JUDGING CONTESTS AS A TEACHING METHODOLOGY

Judging competitions and contests have been a tool for teaching students about agricultural concepts for over 100 years, and have included livestock judging, horse judging, meat judging, wool judging, and dairy judging. This teaching tool has been used in 4-H competitions, FFA contests, as well as at the collegiate level. A survey of judging team alumni found that commonly cited personal benefits included communication skills, confidence, animal evaluation skills, and decision-making skills (Mccann et al., 1992). Many of these alumni indicated that the judging team program was a part of their college selection decision, and as alumni, they have contributed to the college and/or the judging program. A survey of universities with agricultural programs found that 84.6% of the 39 respondents sponsored at least one animal related judging team (Field et al., 1998). Again, the most frequently stated outcomes of participation on a judging team included communication ability, logical decision-making,

industry knowledge, and teamwork. Specific to dairy cattle judging, specific skills identified included critical thinking, self-discipline, situation analysis, decision making, organization, verbal expression and defense of decisions, all of which are critical life skills (Guthrie and Lee Majeskie, 1997). The judging team model has proven to be a successful way to teach students not only about animal agriculture, but learning necessary skills for a career in the agricultural industry.

HISTORY OF THE ANIMAL WELFARE JUDGING AND ASSESSMENT CONTEST

The Animal Welfare Judging and Assessment Contest (AWJAC) was created in 2002 to teach students how to assess and critique the welfare of animals used for food production, research, companionship, and other purposes (Heleski et al., 2003). The format was modeled after traditional judging competitions, with the aim to improve retention of information about animal welfare science by application to simulated situations. The contest enables students to critically examine a situation by gathering information and using it to make an assessment of welfare quality. Each year four different animal species are featured, with representation from multiple aspects of animal use, including livestock, companion, research, and zoo animals.

The first contest was held at Michigan State University in 2002, with four undergraduate teams representing four institutions (Heleski et al., 2002). A survey administered after that first event found that 94% of students stated that their animal welfare knowledge had increased, and 100% of respondents thought the competition was a good idea, and they would encourage other students to participate (Waltman et al., 2002). Since 2002, the contest has been held on an annual basis, at several different host institutions. The contest initially included only undergraduate students, though has now grown to include graduate and veterinary students. The veterinary division was added in 2008 with support from the AVMA (AVMA, 2016a). The veterinary

division has now become the largest segment of the contest, indicating an increasing interest in animal welfare education in veterinary students (Nolen, 2013). While all three divisions only compete against other students within that division, they all view the same scenarios. In 2014, there were a total of 28 teams and 116 students competing, representing institutions from the United States, Canada, the Caribbean, and Ireland, making it a truly international contest. According to Zanella, one of the contest's founders, this framework has "revolutionized teaching of animal welfare at many institutions" (Zanella, 2008).

While modeled after traditional judging contests, the animal welfare judging contests has some unique differences. A live animal/team assessment scenario has been incorporated into the contest, but the remaining judging classes/scenarios have been developed using PowerPoint software with videos, photos, graphs, and text information about the management of different animal species (Heleski et al., 2003). This contest has identified that animal welfare is laden with both science and ethics, hence the title of the contest: "Intercollegiate Animal Welfare Judging/Assessment Contest." *Assessment* refers to making objective and quantifiable evaluation of animal welfare, while *judging* refers to the ethics-based choice of what is deemed acceptable animal welfare (Heleski et al., 2003). By incorporating background information about animal welfare and ethics, norms for the species featured at the competition that year, and current scientific literature related to the topic, and applying this information to specific problems, students improve retention of information and take ownership in the learning process (Mench, 2008).

HOW AN ANIMAL WELFARE JUDGING AND ASSESSMENT CONTEST WORKS

The contest is a two-day event. The first morning includes a lecture series by experts on each of the four species featured that year. The speakers cover issues specific to the welfare of

those species, how to perform animal welfare assessments on those species, and unique challenges. The speakers are usually invited to the contest to judge a species in their area of expertise, and they are usually veterinarians or ethologists.

The team assessment occurs during the afternoon of the first day. Teams within one division consist of 3-5 students from one institution. The host institution determines the species for the team assessment. Examples from the past include Jersey dairy heifers, beef cows and calves, teaching and research dairy cows, and laboratory mice. Teams are given a question or a task before arriving at the facility. Upon arrival, the teams are given a timed tour of the facility, including information about all aspects of the animals' care and use. Students are encouraged to perform welfare assessments, such as evaluating the animals' body condition scores or flight zones, while on the tour. At the conclusion of the tour, the team has a defined amount of time to prepare as a group. The teams provide their animal welfare assessment to a panel of judges in the form of timed oral reasons. Judges evaluate the students' knowledge of welfare science, integration of information and scientific references, and overall presentation skills.

The second day of the contest features individual animal welfare assessments on the three remaining animal species. Computer-based scenarios are presented, containing data, videos, and photos of animals under two comparable situations. The students evaluate the different situations for each of the three species, rank the situations based on overall animal welfare, prepare their analysis, and make an oral presentation to expert judges. The judges view the scenarios at the same time as the students, and the judges decide together what the "correct" ranking for the scenarios will be. Again students are scored on their presentation skills, the correct ranking of the scenarios, and their knowledge of animal welfare science.

The contest concludes with an awards ceremony at the end of the second day. For each division, the top individuals and schools are recognized for their accomplishments. The judges provide their reasons for scenario ranking, as well as information they were looking for from the students.

CSU VETERINARY TEAMS

The first Colorado State University (CSU) veterinary team competed at the contest in 2014. At CSU, the veterinary team meets weekly during lunch throughout the fall semester as an extracurricular group. Additionally, students on the veterinary team are encouraged to attend the undergraduate course whenever possible, particularly on days with guest speakers or field trips. Obligations of the veterinary curriculum impede veterinary students from attending all class sessions, necessitating a separate weekly meeting. At CSU, an integrated approach to teaching animal welfare has been adapted to facilitate relationship building between the veterinary school and the Department of Animal Sciences, so there is much overlap between the undergraduate course and the veterinary team preparation. For institutions without an undergraduate course, preparation for the contest can be accomplished with weekly lunch meetings, as was the experience of the first author as a veterinary student at Michigan State University. Field trips are highly encouraged, which can be scheduled on weekends, to give students an example to compare the situations they will encounter at the contest with. At CSU, field trips for each of the four animal species are scheduled by reaching out to the surrounding community.

Veterinary students from all years are invited to participate, though historically the team has consisted of only first and second year veterinary students since third and fourth year students are in clinical rotations. The schedule for the veterinary team mirrors the undergraduate course, with a greater emphasis placed on reading the scientific literature and less on field trips

and guest speakers. The semester begins with an overview of general animal welfare principles, followed by an in depth evaluation of the welfare and management of each of the four animal species. Practice scenarios are incorporated as much as possible into the preparations for the veterinary team (practice scenarios are available on the contest website at www.awjac.org).

The contest is generally held in November, with entry forms due in October. Prior to the entry form deadline, a mock competition, using only one species, modeled after the actual contest helps determine who will be traveling to the contest representing Colorado State University. The students are told what the species will be at least one week in advance. Students view the scenario together. After having time to prepare, each student individually presents oral reasons to a panel of judges. Scores are tallied, and the teams are announced to the students. Students not selected to represent CSU at the competition are still encouraged to participate in the course and the team meetings.

PREPARING FOR THE CONTEST – AN EXAMPLE FROM COLORADO STATE UNIVERSITY

CSU first competed at the Animal Welfare Judging and Assessment Contest in 2012, with an undergraduate team and a graduate team. In 2012, the teams were considered an extracurricular activity, and students met for one hour per week to prepare. Since then, team preparation at CSU has evolved into a course designed for undergraduate students, plus extracurricular graduate team and veterinary team meetings. The undergraduate course is offered in the Department of Animal Sciences for two credits, with four hours of class per week during the fall semester. The course is designed for junior and senior level students as an opportunity to integrate knowledge acquired in other Animal Science courses. At CSU, all three teams form a

cohesive unit, and though not all students are able to participate in all activities, it has helped to create a culture of animal welfare that crosses colleges and departments.

The primary pedagogy of the course is active learning, as this allows the students to take ownership of the learning process (Seeler et al., 1994; May and Silva-Fletcher, 2015). The first week of class focuses on orientation to the course and to the Animal Welfare Judging and Assessment Contest. We review the course syllabus and schedule, explore the contest using a PowerPoint presentation, and practice a scenario evaluation as a group. Students who have participated in previous years assist in orienting the new class. Before focusing on the target species of the current year's contest, the course first covers general animal welfare principles, including different ways of approaching animal welfare science, how to conduct an animal welfare assessment, and historical principles of animal welfare. The Five Freedoms of Animal Welfare are used as a starting point for animal welfare assessment, and historically this was a turning point for animal welfare awareness (Farm Animal Welfare Council, 1992). The AVMA Animal Welfare Principles are utilized as core animal welfare principles (AVMA, 2016b). Animal ethics regarding animal use is incorporated into this portion of the course. Scientific journal articles covering these topics are assigned reading for the students, and the format of these class sessions are generally facilitated group discussions. This teaching strategy allows students to synthesize and integrate information, exposes them to diversity in thinking, and encourages students to prepare for each class session (Bonwell and Eison, 1990). Class size is limited to 15 students, allowing for successful class discussions. The 2015 class had seven enrolled students, plus three graduate students and five veterinary students, with several other students that participated in some of the team events. Guest lecturers are included throughout the course, and have included Dr. Temple Grandin, an animal behaviorist at Colorado State

University, and Dr. Bernard Rollin, an animal ethicist, for this section. Guest speakers provide real-world context, and give students an outside perspective (Mullins, 2001).

The undergraduate course also has a mock competition modeled after the contest, featuring one animal species. The mock competition is used to determine who will be representing CSU at the annual contest. Students who do not make the team are still encouraged to participate in all team events and contest preparation, including class sessions, field trips, and volunteer events.

The remainder of the course focuses specifically on the four species featured at the contest that year. Guest lecturers with expertise on these species provide the students with an overview lecture about animal management and welfare. These lectures generally consist of a PowerPoint presentation with questions and discussion. Learning from experts about the most important animal welfare issues for each of the four species helps students prioritize their independent study (Mullins, 2001). It also gives them key people to reference when preparing oral reasons at the contest.

After the guest lecture, field trips are arranged for students to gain experience and observation firsthand for each of the four animal species. Benefits of field trips include enhanced synthesis of information, skills in research collaboration, confidence, self-efficacy, and improved cognitive reasoning ability (Lei, 2010). For elephants in 2015, the class traveled to the Denver Zoo for a behind-the-scenes tour of the new elephant exhibit. One of the zoo veterinarians, an elephant zookeeper, and several zoo trainers gave the students a tour of the facility, an overview of the elephants in the facility, and answered questions regarding elephant welfare. The field trips give the students exposure to a variety of aspects of animal use, and help students develop connections in the industry. Having some experience with each of the four species featured at the

contest gives students a basis for evaluating the scenarios when making their animal welfare assessments and preparing their oral reasons.

For each of the four species, students are tasked with finding scientific journal articles related to animal welfare and management. Students are instructed to focus on topics including nutrition, housing requirements, behavior, health, painful procedures, use, and enrichment strategies. At least one class period is devoted to each of the four species, with students summarizing articles and key points, and identifying gaps in their knowledge. Each student presents the articles they reviewed, allowing them to learn by teaching. This technique has been shown to benefit both the student presenting the information and the students learning from them (Goldschmid and Goldschmid, 1976). All articles found by the students are shared with all CSU animal welfare judging teams using Google Drive.

Some class sessions are devoted to practice scenarios from past contests to help prepare animal welfare assessment and oral reasoning skills (figure 1). The first several practice scenarios are conducted as a group. As students become more proficient at conducting welfare assessments, they individually rank the scenarios and present oral reasons to the class. Students are occasionally videotaped so they can watch themselves present, and identify areas for improvement. Feedback from peers and from instructors is provided to students to help improve presentation quality. Self-reflection and peer feedback can significantly improve oral presentation skills (De Grez et al., 2009). At the contest, oral reasons are timed, so practice sessions using the time requirements for the contest are important. Several practice team assessments help prepare the students to work as a team, determining their strategy for presenting their reasons together. Oral presentation skills are essential for future success, whether interacting with clients or presenting research findings at a conference.

The primary objective of the course is to prepare students for the annual Animal Welfare Judging and Assessment Contest. This vehicle helps to excite students about animal welfare, while teaching them how to search the scientific literature regarding animal welfare issues. In order to meet the primary objective, some class time is devoted to fundraising and planning travel to the contest. After the contest, the final project for the students is to prepare a scenario on a species of their choice (which may or may not be one of the species at the competition that year), complete with reasons and references. The final class periods are dedicated to presenting these scenarios. These scenarios are used in future classes for preparation for the contest, and feedback from students regarding the assignment has been strongly positive. Creating their own scenario provides students the opportunity to apply all of the skills they have acquired throughout the semester to studying the welfare of one of their favorite animal species.

OUTCOMES OF THE CSU TEAMS

Since the creation of the CSU Animal Welfare Judging Team in 2012, student participation and involvement have dramatically increased. The CSU teams have consistently performed well at the contest, with both individual students and teams winning numerous awards. Being successful at the contest requires strong oral presentation skills, the ability to thoroughly study the scientific literature, and a strong background knowledge on the welfare of the species prior to the contest due to its timed nature. Personal observation of student improvement throughout the semester as well as student self-reflection has shown that all of these outcomes occur as a result of the course and the extracurricular meetings.

In addition to being successful at the contest, the team has sparked an interest in animal welfare at CSU. Participating students have committed to not only learning about animal welfare, but also improving animal welfare in the local community. For example, in 2013,

donkeys were one of the featured species. All of the CSU teams (undergraduate, graduate, and veterinary) took a field trip to Longhopes Donkey Rescue to learn about donkey welfare. After the completion of the course, the students decided to give back to the organization by collecting donated supplies and volunteering at the rescue. The course only runs during the fall semester to coincide with the annual contest, but a group of undergraduate students did not want the conversation to end with the course. They created the Animal Welfare Science Club at CSU, a student organization devoted to learning about animal welfare through guest speakers, journal clubs, field trips, and movies. The Animal Welfare Science Club is housed within the Department of Animal Sciences, but membership includes undergraduate, graduate, and veterinary students. Relationships between undergraduate, graduate, and veterinary students have developed because of participation in the team, with all students having a common interest in animal welfare.

The contest provides an opportunity for students to network with others passionate about animal welfare, including students and experts in the field. Several CSU students have established future graduate advisor relationships at the contest, and many friendships have developed over the years. The first evening at the contest includes a dinner and social event to facilitate networking among participants. This event has proven a valuable benefit of the contest.

Undergraduate student surveys conducted at CSU have shown that 100% of participating students improved their knowledge about animal welfare topics when comparing surveys from the first day of class to the last day of class. Greater than 90% of students over three years have rated the course as excellent. While much of the standard curriculum is designed to teach facts about animal production and medicine, this experience provides students an opportunity to step back and discuss values, ethics and the implications of different practices on animal welfare.

SUMMARY

The Animal Welfare Judging and Assessment Contest provides a unique educational opportunity for veterinary, graduate, and undergraduate students to learn about animal welfare assessment plus oral presentation skills. Preparation for the contest takes time and dedication during the fall semester, but students are rewarded with improved knowledge on animal welfare, better literature review skills, and enhanced oral presentation techniques, based on student success at the competition and evalutions. Networking with other people interested in animal welfare provides an added benefit to competing. Here we have provided an example of one successful approach to developing and conducting animal welfare teaching in the context of the welfare judging contest.

Figure 4.1. Sample Animal Welfare Scenario on Beef Cattle. 1a shows a slide explaining the cattle handling at two different ranches. 1b shows the morbidity and mortality of cows and calves on the same two ranches. During an animal welfare assessment, students must weigh the better handling on ranch 1 with the higher morbidity and mortality on ranch 1 when making their assessment.

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CHAPTER V: FACTORS ASSOCIATED WITH COLOSTRUM QUALITY AND PASSIVE TRANSFER STATUS OF DAIRY HEIFER CALVES ON U.S. DAIRY OPERATIONS

INTRODUCTION

Passive transfer of immunity via colostrum is essential for the short- and long-term health of dairy calves. Researchers have understood the importance of colostrum for over 100 years (Crowther and Raistrick, 1916), yet 19.2% of calves in the US still had failure of passive transfer in 2007 with a serum IgG less than 10 g/L (Beam et al., 2009). Consumption and absorption of maternal immunoglobulins via colostrum is critical for calves to resist infections in the first weeks of life since they are essentially agammaglobulinemic at birth (Gulliksen et al., 2008). The primary components of colostrum contributing to passive immunity are immunoglobulins, which include IgG, IgA, and IgM, with IgG comprising about 85% of the immunoglobulin in colostrum (Larson et al., 1980). Relative to IgG content, high quality colostrum has been defined as having an IgG concentration of greater than 50 g/L (McGuirk and Collins, 2004). Colostrum also contains important nutrients, such as protein, vitamins, minerals and colostral fat that provides the neonatal calf with supplemental heat energy. Factors previously found to be associated with colostrum quality include parity, breed, and season of calving (Gulliksen et al., 2008). The focus of much recent colostrum research has been on management factors for adequate passive transfer, including timing and volume of colostrum fed. Colostrum quality can vary significantly among cows and is an important variable impacting adequate passive transfer of immunity that needs further evaluation.

The four most important factors related to colostrum management for adequate passive transfer are colostrum quality, quantity, timing of feeding, and cleanliness (McGuirk and Collins,

2004). Calves are only able to absorb large molecules, including immunoglobulin, during a brief time period of up to 12 to 24 hours following birth (Michanek et al., 1989). Bacterial contamination of colostrum can lead to decreased absorption of immunoglobulins due to competition at the intestinal epithelium (Stewart et al., 2005; Johnson et al., 2007). Calves are considered to have failure of passive transfer (FPT) if their serum IgG concentration is less than 10 g/L when measured between 24-48 hours of age (Godden, 2008). While 10 g/L is considered the cutoff value for FPT, calves with serum IgG concentrations greater than 15 g/L have been shown to be better able to avoid respiratory infections (Furman-Fratczak et al., 2011). Another study recommended using 20 g/L as the cutoff value for adequate passive transfer of immunity (Chigerwe et al., 2015). FPT has been shown to increase calf morbidity and mortality and decrease calf growth (Robison et al., 1988; Wells et al., 1996; Furman-Fratczak et al., 2011; Nocek et al., 1984). FPT can also decrease productivity, including decreased first and second lactation milk production and increased culling rate during the first lactation (DeNise et al., 1989; Faber et al., 2005). Because of the serious consequences associated with FPT, colostrum management has been a focus of producer education programs (BAMN, 2001).

The objective of this study was to determine the environmental factors and management practices associated with colostrum quality and passive transfer status of Holstein dairy heifer calves.

MATERIALS AND METHODS

Study Design

The USDA National Animal Health Monitoring System (NAHMS) conducts national surveys to collect information on the health, management, and productivity of domestic livestock

species (USDA, 2016). In 2014, a nationwide survey was conducted to collect information about the US dairy industry, including an 18-month longitudinal dairy heifer calf study.

The calf component was part of the NAHMS Dairy 2014 study, and consisted of a convenience sample of 102 dairy operations. These operations were located in 13 states, including California, Colorado, and Washington in the west region, and Iowa, Michigan, Minnesota, Missouri, New York, Ohio, Pennsylvania, Vermont, Virginia, and Wisconsin in the east region (Figure 5.1). Dairy operation size was categorized (based on the number of mature cows) as small (30 to 99 cows), medium (100-499 cows), and large (500 or more cows).

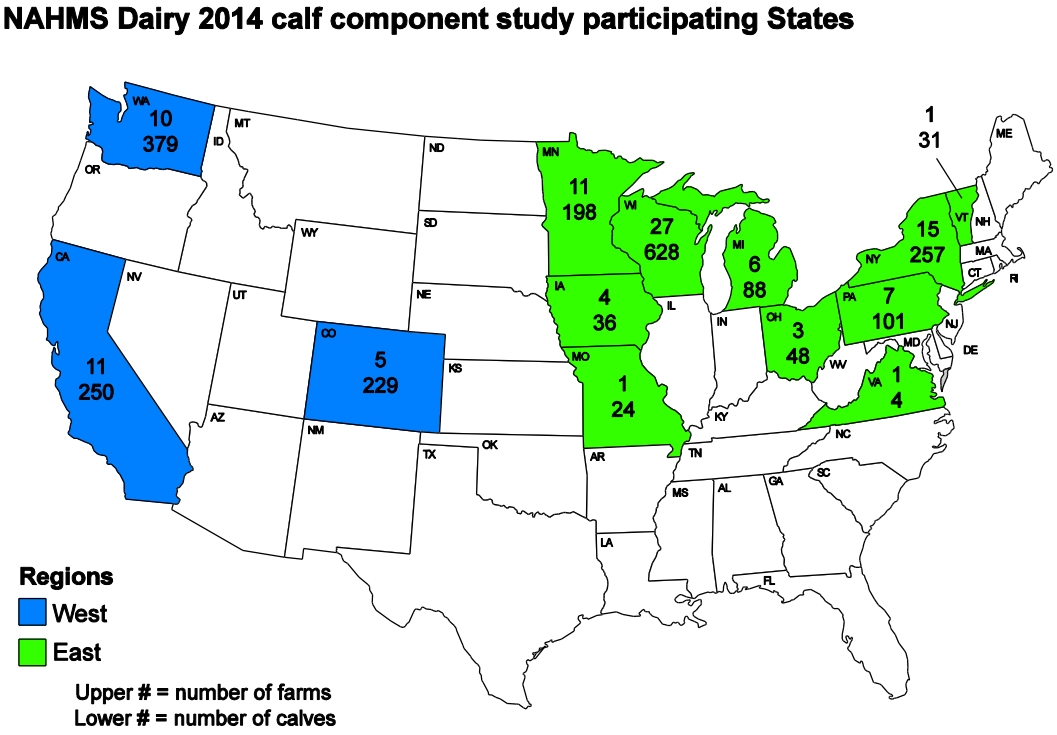

Figure 5.1. Map of states participating in the calf component of the Dairy 2014 study. Regions were defined as West (blue states) and East (green states). Each state that participated shows the number of participating operations on top and the number of calves sampled on bottom.

Data collection for the calf component of the study occurred between March 2014 and September 2015. Each operation was initially instructed to enroll 24 heifer calves over a one-year period, or an average of 2 calves per month. Due to fewer operations participating than

originally planned, the number of calves that could be enrolled per operation was increased to a range of 48 to 60. Additionally, since enrollment of farms did not occur as quickly as had been anticipated, the study encompassed 18 months instead of the 12 that were originally planned.

Heifer Calf Health Card

Each calf enrolled in the study had a Heifer Calf Health Card (Calf Card) to record information on events that occurred between birth and weaning (see appendix). The Calf Card included questions in English and Spanish, and was filled out by the producer, the calf handler, a veterinary medical officer, extension personnel, veterinarians, or a combination of the people involved with calf raising. Sections included on the Calf Card included birth data (such as birth date, weight, and calving ease), colostrum feeding data (including timing, volume, and method of colostrum feeding), pre-weaning housing and procedure data (such as housing, ventilation, bedding, and dehorning), milk feeding (including type of liquid diet fed, any additives, and method of feeding), milk consumption record (volume and frequency of feedings), pre-weaning biweekly growth record (hip height and heart girth recordings), biologic sampling record (including serum collection date), vaccinations, disease incidence and treatment, weaning data (weaning date, primary weaning criteria), and any additional notes. Additional information requested included starter feed labels and milk replacer feed labels (if applicable).

Biological Sampling

Prior to enrollment in the study, calves were screened for persistent infection with bovine viral diarrhea virus (BVDV). V-cut ear notchers were used to collect ear notch samples from all calves, which were tested on-farm for BVDV using the IDEXX SNAP ® BVDV Antigen Test (IDEXX, Westbrook, Maine). Calves positive for BVDV were excluded from the study. Colostrum samples (40-50 ml) from the first feeding of colostrum administered to the calf were

collected in conical screw-top tubes and frozen until shipping. Blood samples (5 ml) from calves between 1-7 days of age were collected in serum separator tubes, and samples were centrifuged if possible prior to shipping. Colostrum and serum samples were shipped together on ice to the National Veterinary Services Laboratory (NVSL) in Ames, Iowa. Samples were accumulated at NVSL and shipped in batches to the Saskatoon Colostrum Company in Saskatoon, Saskatchewan, Canada. Colostrum and serum samples were tested for IgG concentration using radial immunodiffusion. Results from blood samples collected within 24 hours of birth or after 7 days of age were excluded from this analysis.

Radial immunodiffusion (RID) was used to measure the concentration of colostrum and serum IgG. Each 24 mL agarose plate was punched with 42 wells (of 6 uL volume). Wells 1-4 and 39-42 were for two replicates of each of the 4 calibrators used to generate the standard curve, wells 5-9 and 10-14 were for each of the 2 reference standards that were used to qualify the plate, and wells 15-38 were used for test samples. Serial 2-fold dilutions (1/4, 1/8, 1/16, 1/32) of the Bovine IgG Standard (Bovine Serum Calibrator Cat. #4005, Midland BioProducts, Corp.), Reference Bovine Serum (CVB bovine IgG species standard working stock is further diluted 1/4) and Reference Colostrum (diluted 1/15) were prepared in PBS. A 1/4 dilution of test serum and a 1/15 dilution of test colostrum were prepared using PBS. Two replicates of 4 µL of each dilution of the Bovine IgG Standard were dispensed for the standard curve. Two replicates of 4 µL of the diluted reference colostrum and reference serum and 4 µL of the diluted test sample were dispensed on the plate. The plates were incubated at 20-25ºC for 18-19 hours in a humidified chamber. A plate reader was used to measure and record the ring diameters for the precipitin rings surrounding the wells. Using the results (ring diameters) obtained for each of the 2-fold dilutions of the Bovine IgG Standard and an Excel spreadsheet with calculation formulas, a

regression line was generated for each plate for the variables R (ring diameter) versus log10 (concentration). The plate was considered acceptable if the R2 was greater than 0.97 for the standard curve, and the mean values for the reference colostrum and reference serum were the expected values ±10%. Ig concentration for the test sample was determined using the regression line of the Bovine IgG standard obtained for each plate. The diameters were entered into a template where the regression line and Ig concentration (g/L) was calculated.

Environmental Factors

Monthly temperature and humidity index (THI) data by state and county were obtained from the National Oceanic and Atmospheric Administration (NOAA, 2016). THI provides an index that accounts for the effects of temperature and relative humidity, and the equation uses the dry bulb temperature (T, °F) and the relative humidity (RH). The equation for THI used for this analysis was: THI=T – (0.55 – (0.55*RH/100)*(T – 58). Each calf was assigned a THI value for the month prior to birth for colostrum quality analysis and for passive transfer analysis. THI were then categorized according to the thermal neutral zone for a mature cow as follows for the month prior to birth for the analyses: <40, ≥40 and <70, or ≥70.

Day length data were obtained from the United States Naval Observatory for each state, and averaged by month as hours and minutes of light per day (USNO, 2016). Each calf was assigned a day length value for the month prior to birth for colostrum quality analysis, and the month of birth for passive transfer analysis.

Statistical Analysis

When each calf was weaned, the Calf Card was mailed to USDA NAHMS. Initial validation was performed on every calf card prior to data entry to check accuracy of dates and other information. Data were then entered into SAS software (version 9.4; SAS Institute Inc.,

Cary, NC). After all Calf Cards were entered, the data were validated again by the NAHMS staff and merged with the results from the colostrum and serum testing obtained from the laboratory. Descriptive data were analyzed using the FREQUENCY and MEANS procedures for categorical and continuous variables, respectively.

Models were constructed to determine the factors associated with colostrum IgG and serum IgG concentrations, with operation as the random variable. Predictor variables were considered for the models based on biological plausibility. For this analysis, only Holstein heifer calves with data for all of the variables initially included in the models were eligible. For both colostrum and serum IgG model building, univariate screening was used. Variables with a $P<0.20$ in the univariate screening were considered for inclusion in the multivariable model. Stepwise backward elimination model selection in PROC MIXED was used to construct the final models, with $P<0.05$ considered significant, thus included in the model.

RESULTS

Colostrum Quality

Data analysis for colostrum quality included 1,972 Holstein heifer calves. Only Holstein heifer calves were included in the analysis due to known breed differences in colostrum quality and the small sample size obtained for other breeds. The mean colostrum IgG concentration was 74.4 g/L (SE 0.72), with 77.4% of samples having colostrum IgG levels greater than 50 g/L (Table 5.1).

Table 5.1. Percent of Holstein heifer calves for all categorical variables initially included in colostrum IgG univariate screening, by colostrum IgG category. Bolded variables were included in the initial colostrum IgG model (*P-value* less than 0.20).

Initial model variable	Variable level	Calves (n)	Calves (%)	Calves by Colostrum IgG (%) Poor ≤40 g/L	Fair >40, ≤50 g/L	Excellent >50 g/L	*P-value*
All calves		1972	100.0%	13.2%	9.4%	77.4%	
Region	West	772	39.1%	13.3%	7.6%	79.0%	0.695
	East	1200	60.9%	13.2%	10.5%	76.3%	
Herd size (adult cows)	Small (30-99 cows)	282	14.3%	22.7%	10.3%	67.0%	0.229
	Medium (100-499 cows)	549	27.8%	11.8%	9.3%	78.9%	
	Large (500+ cows)	1141	57.9%	11.6%	9.2%	79.2%	
Heat treatment of colostrum	Yes	123	6.2%	4.1%	13.8%	82.1%	0.587
	No	1842	93.4%	13.9%	9.1%	77.0%	
Source of colostrum	Unknown lactation	1010	51.2%	10.7%	9.5%	79.8%	**<0.001**
	Commercial colostrum replacer	23	1.2%	56.5%	8.7%	34.8%	
	First lactation dam	321	16.3%	13.4%	11.2%	75.4%	
	Second lactation dam	277	14.0%	19.1%	10.1%	70.8%	
	Third+ lactation dam	341	17.3%	12.9%	6.7%	80.4%	
THI categories	<40	527	26.7%	13.3%	12.5%	74.2%	**0.001**
	≥40, <70	1228	62.3%	12.8%	8.1%	79.2%	
	≥70	217	11.0%	15.7%	9.2%	75.1%	

Initial variables included in the univariate screening for colostrum quality as indicated by colostrum IgG concentration included region, herd size, average day length for the month prior to calving for the state of the operation, categorized average temperature and humidity index (THI) value for the month prior to calving for the county of the operation, heat treatment of colostrum, and source of colostrum (Tables 5.1 and 5.2).

Table 5.2. Continuous variables initially evaluated for colostrum IgG univariate screening, by colostrum IgG category (n=1972).

		Percentiles					Colostrum IgG Category			
Variable	Mean (SE)	5th	25th	50th	75th	95th	Poor ≤40 g/L Mean (SE)	Fair >40, ≤50 g/L Mean (SE)	Excellent >50 g/L Mean (SE)	*P-value*
Day length month prior to calving (hours:minutes)	12:21 (0:03)	8:58	10:17	12:28	14:28	15:30	12:29 (0:09)	12:12 (0:10)	12:21 (0:03)	0.872

After univariate screening and stepwise backward elimination model selection, the variables included in the final model for colostrum IgG concentration were source of colostrum (P<0.001) and a categorized average THI for the month prior to calving (P=0.002) (Table 5.3). Colostrum IgG was highest for third or higher lactation dams (84.7 g/L, SE 2.26). Colostrum IgG from unknown lactation dams, first, and second lactation dams were not significantly different. Commercial colostrum replacers had the lowest colostrum IgG concentration (40.3 g/L, SE 6.72) (Figure 5.2). When THI values of the month prior to calving were 70 or above, the colostrum IgG concentrations were greater than when the THI values were less than 40 (72.6 g/L [SE 2.9] and 64.2 g/L [SE 2.3], respectively).

Table 5.3. Results of multivariable modeling of factors associated with colostrum IgG fed to Holstein heifer calves (n=1972).

Variable	Variable level	Model predicted colostrum IgG (g/L)	Standard error	*F-value*	Final model *P-value*
Source of colostrum	Unknown lactation	73.1	1.90	17.28	<0.001
	Commercial colostrum replacer	40.3	6.72		
	First lactation dam	72.3	2.33		
	Second lactation dam	72.0	2.40		
	Third+ lactation dam	84.7	2.26		
THI categories	<40	64.2	2.34	6.16	0.002
	≥40, <70	68.7	2.07		
	≥70	72.6	2.89		

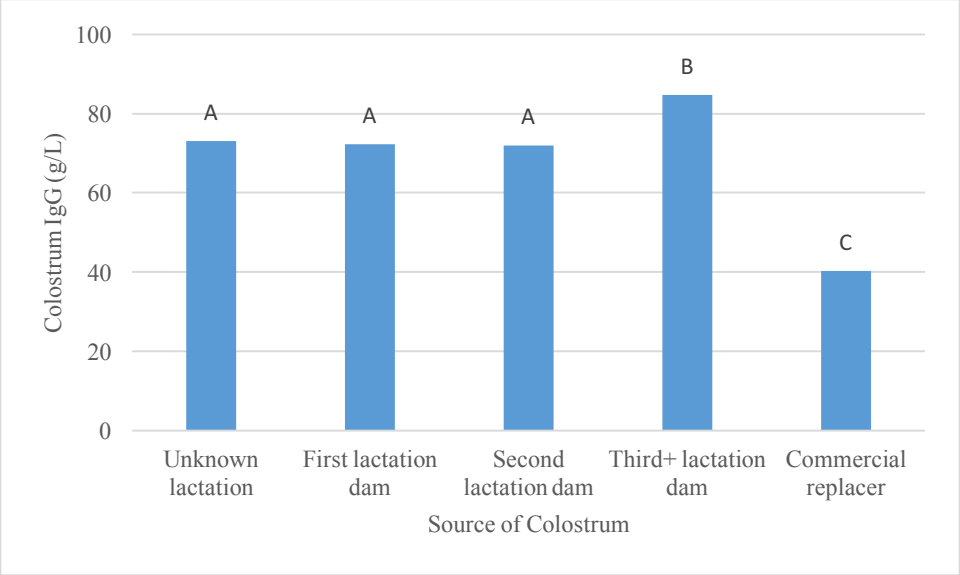

Figure 5.2. Predicted colostrum IgG (g/L) values for different sources of colostrum. Bars with different superscripts are significantly different.

Passive Transfer of Immunity

Data analysis for passive transfer of immunity included 1,623 Holstein heifer calves. To be included in the analysis, calves had to have complete data for all variables included in the initial model. The mean serum IgG was 21.6 g/L (SE 0.25), and 73.3% of calves had serum IgG levels greater than or equal to 15 g/L (Table 5.4).

Table 5.4. Percent of Holstein heifer calves for all categorical variables initially included in serum IgG univariate screening, by serum IgG category. Bolded variables were included in the initial serum IgG model (*P-value* less than 0.20).

				Calves by Serum IgG (%)			
Initial model variable	Variable level	Calves (n)	Calves (%)	Poor <10 g/L	Fair ≥10, <15 g/L	Excellent ≥15 g/L	*P-value*
All calves		1623	100.0%	12.1%	14.5%	73.3%	
Region	West	618	38.1%	9.9%	13.8%	76.4%	**0.166**
	East	1005	61.9%	13.5%	15.0%	71.4%	
Herd size (adult cows)	Small (30-99 cows)	209	12.9%	17.2%	15.8%	67.0%	0.516
	Medium (100-499 cows)	470	29.0%	13.2%	16.0%	70.9%	
	Large (500+ cows)	944	58.2%	10.5%	13.6%	76.0%	

Heat treatment of colostrum	Yes	107	6.6%	4.7%	12.1%	83.2%	**0.081**
	No	1516	93.4%	12.7%	14.7%	72.6%	
Source of colostrum	Unknown lactation	780	48.1%	10.0%	13.7%	76.3%	**<0.001**
	Commercial colostrum replacer	22	1.4%	63.6%	18.2%	18.2%	
	First lactation dam	280	17.3%	9.3%	12.9%	77.9%	
	Second lactation dam	243	15.0%	15.6%	14.4%	70.0%	
	Third+ lactation dam	298	18.4%	13.8%	18.1%	68.1%	
Dam lactation	First	632	38.9%	10.8%	13.9%	75.3%	**0.041**
	Second	431	26.6%	12.8%	15.1%	72.2%	
	Third or higher	560	34.5%	13.2%	14.8%	72.0%	
Number of calves	Single	1566	96.5%	12.2%	14.6%	73.2%	**0.145**
	Twin	57	3.5%	10.5%	12.3%	77.2%	
Method of feeding	Bottle	1025	63.2%	13.8%	13.0%	73.3%	0.771
	Esophageal feeder	167	10.3%	9.0%	18.6%	72.5%	
	Both bottle and e-feeder	32	2.0%	3.1%	18.8%	78.1%	
	Bucket/pail	4	0.2%	50.0%	25.0%	25.0%	
	Suckle	392	24.2%	9.7%	16.6%	73.7%	
Calving ease	Unassisted	1173	72.3%	12.8%	15.2%	72.0%	0.392
	Easy - I person	327	20.1%	9.5%	13.1%	77.4%	
	Difficult - 2 or more people	68	4.2%	16.2%	14.7%	69.1%	
	Mechanical/surgical extraction	23	1.4%	8.7%	4.3%	87.0%	
Calving attendance	Male	778	47.9%	9.5%	12.2%	78.3%	0.428
	Female	69	4.3%	8.7%	10.1%	81.2%	
	Unattended	677	41.7%	14.8%	17.7%	67.5%	
THI category	<40	444	27.4%	11.0%	14.6%	74.3%	**0.187**
	≥40, <70	1008	62.1%	11.3%	15.3%	73.4%	
	≥70	171	10.5%	19.9%	9.9%	70.2%	

Initial variables included in the multivariable model after univariate screening for passive transfer status as indicated by serum IgG levels included region, a categorized average THI value for the month prior to birth for the county, heat treatment of colostrum, source of colostrum, timing to first feeding of colostrum, total volume of colostrum fed in the first 24 hours of life,

age at blood sampling, dam lactation, number of calves, birth weight, and colostrum IgG concentration (Tables 5.4 and 5.5).

Table 5.5. Continuous variables initially evaluated for serum IgG by IgG category for Holstein heifer calves (n=1623). Bolded variables were included in the initial serum IgG model (*P-value* less than 0.20).

		Percentiles					Serum IgG Category			
							Poor <10 g/L	Fair ≥10, <15 g/L	Excellent ≥15 g/L	
Variable	Mean (SE)	5th	25th	50th	75th	95th	Mean (SE)	Mean (SE)	Mean (SE)	*P-value*
Timing to colostrum feeding (hours)	2.9 (0.07)	0.3	1.0	2.0	3.5	8.0	3.9 (0.24)	3.3 (0.18)	2.6 (0.07)	**<0.001**
Total volume of colostrum (L)	4.4 (0.04)	1.9	3.8	3.8	5.7	7.6	4.3 (0.11)	4.4 (0.10)	4.5 (0.04)	**0.029**
Age at blood sample (days)	2.9 (0.04)	1	2	3	4	5	3.0 (0.11)	3.1 (0.10)	2.9 (0.04)	**<0.001**
Birth weight (kg)	43.1 (0.13)	35.9	39.9	42.6	45.8	52.2	43.3 (0.37)	44.0 (0.35)	43.0 (0.15)	**0.010**
Colostrum IgG (g/L)	75.3 (0.78)	26.9	53.1	74.7	93.8	132.1	57.8 (2.24)	64.4 (1.87)	80.4 (0.89)	**<0.001**
First feeding of colostrum volume (L)	3.0 (0.02)	1.9	1.9	2.8	3.8	3.8	2.9 (0.06)	3.1 (0.05)	3.0 (0.03)	0.435
Day length for month of birth (hours:minutes)	12:21 (0:03)	9:03	10:27	12:28	14:28	15:30	12:26 (0:10)	12:20 (0:09)	12:20 (0:04)	0.210

The final multivariable model for serum IgG levels in calves included region (P=0.041), heat treatment of colostrum (P=0.018), source of colostrum (P<0.001), timing to the first feeding (P=0.004), total volume of colostrum fed in the first 24 hours (P=0.013), the age of the calf at blood sampling (P<0.001), and colostrum IgG concentration (P<0.001) (Table 5.6). Serum IgG was the highest in calves that received colostrum from first lactation dams (25.7 g/L, SE 1.11), and was the lowest for calves fed commercial colostrum replacer (16.6 g/L, SE 2.21) (Figure 5.3). Serum IgG was higher for calves fed heat-treated colostrum (24.4 g/L, SE 1.72) compared with calves fed colostrum that was not heat-treated (20.5 g/L, SE 0.61). Serum IgG was higher for calves raised in the west (23.5 g/L, SE 1.25) than for calves raised in the east (21.5 g/L, 0.92).

For each hour delay following birth to colostrum feeding, serum IgG decreased 0.37 g/L (SE 0.11). Within the range of observed colostrum IgG values, for each 1 L increase of colostrum fed in the first 24 hours after birth, serum IgG increased 0.53 g/L (SE 0.21). For every increase in colostrum IgG concentration of 10 g/L, the serum IgG increased 1.1 g/L (SE 0.01). For each day following birth to the collection of the blood serum IgG decreased 0.71 g/L (SE 0.16).

Table 5.6. Results of multivariable modeling of factors significantly associated with serum IgG of Holstein heifer calves (n=1623).

Variable	Variable level	Model predicted serum IgG (g/L)	Standard error	*F-value*	Final model *P-value*
Region	West	23.5	1.25	4.17	0.041
	East	21.5	0.92		
Heat-treated colostrum	Yes	24.4	1.72	5.57	0.018
	No	20.5	0.61		
Source of colostrum	Unknown lactation	23.6	0.86	8.12	<0.001
	Commercial colostrum replacer	16.6	2.21		
	First lactation dam	25.7	1.11		
	Second lactation dam	24.1	1.11		
	Third+ lactation dam	22.4	1.09		
Timing to colostrum feeding (hours)		-0.32	0.11	8.4	0.004
Total volume in 24 hours (L)		0.57	0.21	6.14	0.013
Age at blood sample (days)		-0.71	0.16	20.64	<0.001
Colostrum IgG (g/L)		0.11	0.01	198.71	<0.001

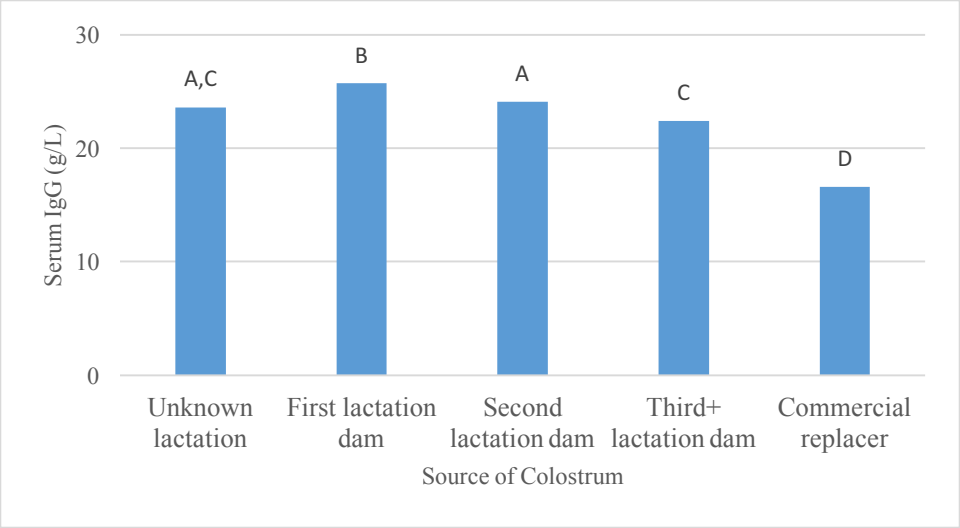

Figure 5.3. Predicted serum IgG (g/L) values for different sources of colostrum. Bars with different superscripts are significantly different.

Failure of Passive Transfer

Calves with failure of passive transfer (FPT) were described in terms of factors commonly associated with FPT. Among calves included in the passive transfer analysis, 12.1% of calves were considered to have FPT of immunity (serum IgG below 10 g/L). Risk factors commonly associated with FPT included poor colostrum quality (colostrum IgG concentration ≤50 g/L), delayed feeding of colostrum (first feeding ≥4 hours after birth), and low total volume of colostrum fed in the first 24 hours (<3.79 L of colostrum). In this study, the administration of poor quality colostrum (colostrum IgG concentration ≤50 g/L) accounted for 46.4% of calves with FPT (Table 5.7). Of the calves with FPT that received excellent quality colostrum (colostrum IgG concentration >50 g/L), 33.0% had delayed feeding of colostrum, and 51.9% were fed a low total volume of colostrum within the first 24 hours after birth. Overall, 14.2% of calves with FPT had no apparent risk factors for FPT; they received high quality colostrum within 4 hours after birth, and they were administered greater than 3.79 L of colostrum within the first 24 hours.

Table 5.7. Factors associated with failure of passive transfer (serum IgG <10 g/L) in Holstein heifer calves (n=197).

Received high quality colostrum (>50 g/L IgG)	Fed first colostrum in less than 4 hours	Fed more than 3.79 L of colostrum within 24 hours	% of Calves with FPT (serum IgG <10 g/L)
Yes	Yes	Yes	14.2%
Yes	Yes	No	21.8%
Yes	No	Yes	11.7%
Yes	No	No	6.1%
No	Yes	Yes	4.6%
No	Yes	No	22.8%
No	No	Yes	10.7%
No	No	No	8.1%

DISCUSSION

Colostrum quality is generally defined by the IgG concentration, with greater than 50 g/L considered excellent quality colostrum (McGuirk and Collins, 2004). Results from this study showed that overall colostrum quality available to heifer calves on US dairy farms was excellent. The mean concentration of 74.4 g/L of IgG was significantly higher than 50 g/L and similar to the mean colostrum IgG concentration of 68.8 g/L previously reported (Morrill et al., 2012). Additionally, more than three-quarters of colostrum samples tested (77.4%) were above the target IgG concentration of 50 g/L. This shows significant improvement in colostrum quality since 1992 when 93.3% of samples had colostrum IgG levels below 50 g/L (Shearer et al., 1992). However, 22.6% of colostrum samples in the current study were below 50 g/L of IgG and 9.4% were below 40 g/L. Considering the ease and availability of on-farm assessment tools for colostrum quality, including colostrometers and Brix refractometers, producers should be encouraged to test and avoid feeding poor quality colostrum (Quigley et al., 2013).

Factors associated with colostrum quality included the source of colostrum and the categorized average THI for the month prior to calving. Colostrum IgG concentration was

significantly higher when the THI was greater than 70. Cabral et al. (2016) showed similar results, with a positive correlation between colostrum IgG concentration and number of days above the thermoneutral zone. Colostrum creation begins during the dry period in the weeks prior to calving, so environmental factors that influence colostrum quality would likely have the greatest influence during the month prior to calving (Godden, 2008). One possible explanation is that as the temperature rises, vasodilation leads to increased permeability of the blood vessels, and possibly an increased amount of IgG passes into the colostrum in the mammary gland (Cabral et al., 2016). The authors of that study were unable to determine if temperature or day length were contributing to colostrum quality. In the current study, both factors were included in the multivariable model for colostrum IgG concentration, yet only THI was significantly associated with colostrum IgG concentration. Alternatively, cold stress could have a negative impact on colostrum production. Since THI was collected as a monthly average, extremes were not seen at either end. Relatively few calves received colostrum samples (11.0%) collected in the heat stress zone for cattle (THI≥70), so perhaps the potential negative impact of heat stress on colostrum formation was not detected in this study.

The source of the colostrum was also associated with colostrum quality. Colostrum samples from dams in third or higher lactation had the highest quality colostrum, as was previously shown by Tyler et al. (1999). As cows age, they are exposed to more farm-specific pathogens, potentially increasing the IgG concentration in the colostrum (Godden, 2008). A common practice is to discard colostrum from first calf heifers (Tyler et al., 1999), yet these results showed no significant difference in colostrum quality between first and second lactation dams. Colostrum samples from pooled samples, other dams, or dams without lactation information were categorized as unknown lactation. The colostrum quality for unknown lactation

was closest to first lactation dams, and between first and third or higher lactation dams. This was as expected since these samples likely came from first and second lactation dams as they represent the majority of cows on farm.

Commercial colostrum replacer had the lowest levels of IgG, with a mean of only 39.5 g/L. This study did not differentiate between colostrum supplements and colostrum replacers, and only 23 calves were administered any type of colostrum replacer. Colostrum supplements tend to have low levels of IgG with poor absorption, especially if used as a colostrum substitute, since they are intended to add IgG to poor quality maternal colostrum (Godden and James, 2014). Colostrum replacers vary widely in their concentration of IgG, though they should provide a minimum of 100 g of IgG per dose (Quigley et al., 2001; Godden and James, 2014). Feeding two doses of lacteal-derived colostrum replacer for total IgG consumption >200 g decreased the risk of FPT compared with feeding raw pooled colostrum, making lacteal-derived colostrum replacers a viable alternative for preventing FPT when fed properly (Pithua et al., 2011). While colostrum replacers can be used when high quality maternal colostrum is unavailable or when trying to minimize disease transmission to the calf via colostrum, natural colostrum from on the farm often has higher IgG levels in addition to protection against farm-specific pathogens. The variability in colostrum quality suggests that it is advisable to test all colostrum on farm for indicators of IgG concentration (such as a Brix refractometer or a colostrometer). Producers should feed only high quality colostrum or feed colostrum products with known mass of IgG that is >50 g/L when reconstituted.

Passive transfer of immunity can be estimated using total protein or a Brix refractometer, however measuring the serum IgG concentration gives the most accurate indication of passive transfer status (Deelen et al., 2014). Calves with serum IgG levels below 10 g/L are considered

to have failure of passive transfer, and calves with serum IgG levels above 15 g/L are considered to have excellent passive transfer of immunity. Overall, calves in this study had excellent passive transfer with an average serum IgG of 21.6 g/L, and 73.3% of calves had excellent passive transfer.

Factors associated with serum IgG included region, heat treatment of colostrum, source of colostrum, timing to the first feeding, total volume of colostrum fed in the first 24 hours of life, the age of the calf at blood sample, and colostrum IgG. The age of the calf at blood sample was included in the model as a covariate due to the known decrease of serum immunoglobulins during the first month of life (Tóthová et al., 2015). The calf's age at the time of blood collection was significantly related to serum IgG in the final model, with serum IgG decreasing as days of age at sampling increased.

The source of the colostrum had a different effect on serum IgG than colostrum IgG. The highest serum IgG levels were in calves fed colostrum from first lactation dams, followed by second lactation dams, unknown dams, third or higher lactation dams, and lowest for commercial colostrum replacer. There was a correlation between dam lactation and birth weight; calf birth weight increased with increasing parity. During a preliminary analysis using a subset of the final dataset, birth weight was negatively associated with serum IgG. Perhaps this explains why calves from first lactation dams had the highest levels of serum IgG despite the opposite effect of lactation on colostrum quality. Since the commercial colostrum replacers fed had the lowest colostrum quality, it is not surprising that calves that received it as their source of colostrum had the lowest serum IgG levels. Additionally, absorption of IgG from serum-derived colostrum replacers has been shown to be lower than from natural colostrum (Garry et al., 1996; Quigley et al., 2002; Swan et al., 2007). The source of IgG in colostrum replacers greatly influences

absorption, with colostrum-derived replacers generally having better absorption compared with serum-derived replacers (Godden and James, 2014).

A calf's enterocytes have the ability to nonselectively absorb large molecules, including IgG, by pinocytosis. These molecules are transported across the cell and deposited into the lymphatic system via exocytosis (Godden, 2008). From there, the molecules are absorbed into the bloodstream through the thoracic duct. This process decreases linearly from the time of birth until gut "closure" at approximately 24 hours of age. Because of this, the timing of colostrum feeding is the most important factor for efficient absorption of IgG. The results of this study found that serum IgG decreased by 0.37 g/L for every hour following birth that colostrum was administered. Most experts recommend feeding colostrum as soon as possible after birth, and always within the first four hours of life (Michanek et al., 1989; BAMN, 2001).

An adequate amount and quality of colostrum is essential for adequate passive transfer of immunity. The general recommendation is to feed at least 10% of body weight of colostrum at the first feeding, which equates to about 4 L for the average size calf (Godden, 2008). This study found that for every 1 L of colostrum administered during the first 24 hours of life, the serum IgG increased by 0.56 g/L, indicating that more colostrum leads to higher passive transfer. Increased serum IgG is related to the total mass of IgG administered to the calf, which can occur by feeding a larger volume of colostrum, feeding a high quality/IgG concentration of colostrum, or both. The final model for serum IgG included both volume of colostrum fed and colostrum IgG concentration. For every 10 g/L increase in colostrum IgG concentration, serum IgG increased by 1.1 g/L, indicating that higher quality colostrum equated to better passive transfer.

Calves that received heat-treated colostrum had higher serum IgG levels than calves that did not receive heat-treated colostrum. Heat treatment of colostrum needs to be performed at a

lower temperature (60ºC) for a longer period of time (60 minutes) compared to milk pasteurization to avoid IgG denaturation. Heat treatment can be used as a tool to reduce bacterial contamination of colostrum (Godden, 2008; Armengol and Fraile, 2016). Johnson and others (2007) showed similar results, with heat-treated colostrum having lower bacterial loads and better IgG absorption. Decreasing the overall bacterial load in the colostrum potentially improves absorption of IgG, though the exact mechanism is not well understood. One theory is that colostrum IgG in the intestinal lumen has fewer bacteria to bind to, resulting in more IgG to be absorbed. A second theory is that colostrum IgG has fewer bacteria to compete with to cross the enterocyte, resulting in increased absorption (Godden, 2008). Only a small percentage of calves were fed heat-treated colostrum (6.3%), so this is a potential area for improvement for colostrum management on farm.

Interestingly, region was associated with serum IgG, with calves in the west having higher IgG levels than calves in the east. While this study tried to account for many management factors, there are potentially other factors that were not accounted for, resulting in the regional association. There was a strong association with THI and region, with the east having a lower average and a narrower range compared with the west. Perhaps cold stress in calves interferes with colostrum absorption, as suggested by Olson and others (1981). Thermal stress can also negatively impact absorption of colostrum IgG (Stott et al., 1976).

Overall, 12.1% of calves had FPT, increasing their risk for morbidity and mortality (Weaver et al., 2000). This study supports the trend of decreasing prevalence of FPT in dairy heifer calves in the U.S. In the 1991-1992 National Dairy Heifer Evaluation Project, more than 40% of calves had FPT (USDA, 1993). In the USDA NAHMS Dairy 2007 study, 19.2% of calves had FPT (Beam et al., 2009). The risk factors evaluated for FPT included poor quality

colostrum (≤50 g/L colostrum IgG), delayed first feeding of colostrum (≥4 hours after birth), and inadequate total volume of colostrum fed in the first 24 hours (≤3.79 L). Among the calves with FPT, 85.8% had one or more of the risk factors that we associated with FPT. All of the risk factors associated with FPT were present in 8.1% of calves with FPT. Among the calves with FPT, 46.2% received poor quality colostrum, resulting in FPT.

Of all of the calves with FPT, 14.2% of calves that had FPT without any of the described risk factors. Colostrum quality was measured in a laboratory, but timing and volume fed were self-reported numbers, and potentially some of the calves with FPT did not receive colostrum at the time indicated, or the total amount reported. Some operations appeared to report based on standard operating procedures, yet there may have been variation at the individual calf level, resulting in FPT. Additionally, other factors associated with absorption of IgG could account for these calves with FPT and no apparent associated risk factors, such as biological variation in gut absorptive function. Bacterial contamination of colostrum was not assessed and may result in decreased absorptive capacity of immunoglobulins (Johnson et al., 2007). In the planning phases of the study, quantifying bacterial concentration in colostrum samples was considered, but due to challenges in consistent sample collection, storage, and shipping, this was not performed.

Since this was a nationwide field study, there were some limitations in study design. A greater number of producers were expected to participate in the study than actually did, making this study a convenience sample rather than representative of dairy heifer management across the U.S. dairy industry. However, the number of calves was large and operations from 13 states participated. There was however a large variation among operations in the quality of the information provided. Data collected on farm included self-reporting on the Calf Card, with

some operations potentially reporting standard operating procedures rather than individual calf level data.

Colostrum quality (colostrum IgG) was most significantly impacted by the source of the colostrum and the categorized THI for the month prior to birth. Colostrum from third lactation dams had the highest IgG concentrations, and commercial colostrum replacers had the lowest IgG concentrations. Colostrum IgG was positively correlated with THI.

Passive transfer (serum IgG) was also impacted by the source of the colostrum, though in a different pattern than colostrum quality, calves receiving colostrum from first lactation dams had the highest serum IgG and calves receiving commercial colostrum replacers the lowest serum IgG. Calves that received heat-treated colostrum had higher serum IgG than calves that received colostrum that was untreated. Geographic region also impacted serum IgG. Serum IgG increased as time to the first feeding decreased, total volume of colostrum fed in the first 24 hours increased, the age of the calves at blood sample decreased, and the quality of the colostrum increased (colostrum IgG). These results indicate that prompt feeding of high-quality colostrum in appropriate amounts following birth, as well as environmental factors, are important to the passive transfer status of dairy heifer calves.

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CHAPTER VI: FACTORS ASSOCIATED WITH AVERAGE DAILY GAIN IN DAIRY HEIFER CALVES ON U.S. DAIRY OPERATIONS

INTRODUCTION

The preweaning phase is a critical period in the life of a dairy heifer, and optimal conditions can set a calf up for success as a lactating cow. Growth determines the age at first breeding and the age and weight at first calving, and is associated with lifetime productivity (Heinrichs, 1993). Growth during the preweaning period, and specifically average daily gain (ADG), is impacted by many different factors, including passive transfer of immunity, disease, nutrition, management practices, and environmental factors (Place et al., 1998). Therefore, ADG is an appropriate metric to evaluate the preweaning period.

Proper nutrition for calves is essential for growth and rumen development. At birth, calves are functional monogastrics, and they rely exclusively on liquid milk diets for nutrients (Drackley, 2008). By about three weeks of age, calves should be consuming adequate amounts of calf starter to stimulate rumen development, and industry recommendations state that calf starter should be offered by 4 days of age (BAMN, 2003). Calves must have access to fresh, clean water in addition to the milk diet in order to stimulate starter feed intake (BAMN, 2003). Protein is considered the rate-limiting nutrient for calf growth (Drackley, 2008). Milk replacers with 20% protein provide enough protein for a 50 kg calf under thermoneutral conditions to gain 0.3 kg/day compared with 0.8 kg/day for the same calf fed a 25% protein milk replacer (NRC, 2001). Calves are most efficient at growth during the preweaning period, then rates of growth steadily decline as they age (Owens et al., 1993; Kertz et al., 1998). Thus, it is important to try to maximize growth during this period.

Historically, calf feeding regimens included twice daily feeding of 10% of body weight total, equating to about 2 L of liquid diet fed twice per day (Thickett et al., 1986). A rationale for limit feeding milk has been to promote starter intake, allowing calves to be weaned earlier, but at a cost in terms of health and growth. More recently, enhanced feeding programs with higher percent protein milk replacers or ad libitum feeding programs using automated calf feeding systems have gained popularity (Jasper and Weary, 2002; Terré et al., 2009). Limiting the liquid diet fed can result in decreased growth (Flower and Weary, 2001), and potentially increase the incidence of disease in preweaning calves.

The objective of this study was to evaluate average daily gain (ADG) in dairy heifer calves based on different health, feeding, and management practices, as well as environmental factors.

MATERIALS AND METHODS

Study Design

The USDA National Animal Health Monitoring System (NAHMS) conducts national surveys to collect information on the health, management, and productivity of domestic livestock species (USDA, 2016). In 2014, a nationwide survey was conducted to collect information about the US dairy industry, including an 18-month longitudinal preweaned dairy heifer calf study.

The calf component was part of the National Animal Health Monitoring System's Dairy 2014 study, and consisted of a convenience sample of 102 dairy operations with Holstein calves. These operations were located in 13 states, including California, Colorado, and Washington in the west region, and Iowa, Michigan, Minnesota, Missouri, New York, Ohio, Pennsylvania, Vermont, Virginia, and Wisconsin in the east region (Figure 6.1). Dairy operation size was

categorized (based on the number of mature cows) as small (30 to 99 cows), medium (100-499 cows), and large (500 or more cows).

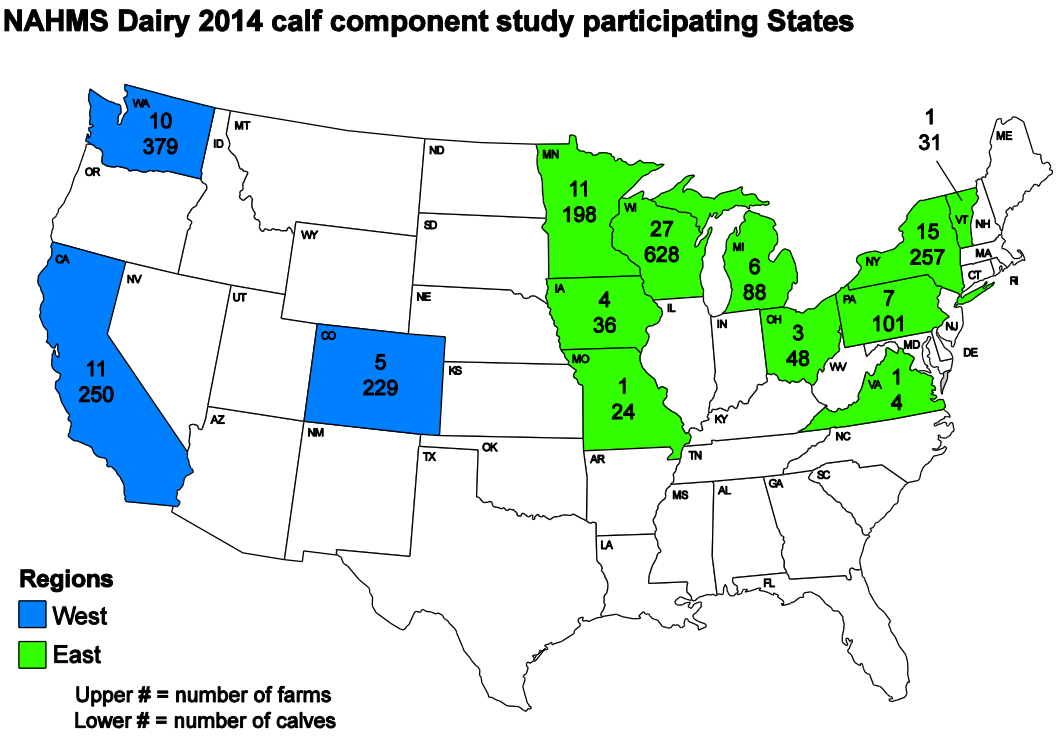

Figure 6.1. Map of states participating in the calf component of the Dairy 2014 study. Regions were defined as West (blue states) and East (green states). Each state that participated shows the number of operations sampled on top and the number of calves sampled on bottom.

Data collection for the calf component of the study occurred from March 2014 to September 2015. Each operation was instructed to enroll 24 heifer calves over a one-year period, or an average of 2 calves per month. Due to fewer operations agreeing to participate than originally planned, the number of calves that could be enrolled per operation was increased to 48-60. Additionally, since enrollment of farms did not occur as quickly as anticipated, the study encompassed 18 months instead of the 12 that were planned.

Heifer Calf Health Card

Each calf enrolled in the study had a Heifer Calf Health Card (Calf Card) filled out to record information on events that occurred between birth and weaning (see appendix). The Calf

Card contained questions in both English and Spanish and was filled out by the producer, the calf handler, a veterinary medical officer, extension personnel, veterinarians, or a combination of people involved with calf raising. Sections included on the Calf Card included birth data (such as birth date, weight, and calving ease), colostrum feeding data (including timing, amount, and method of colostrum feeding), preweaning housing and procedure data (such as housing, ventilation, bedding, and dehorning), milk feeding (including type of liquid diet fed, any additives, and method of feeding), milk consumption record (amount and frequency of feedings), preweaning biweekly growth record (hip height and heart girth recordings), biologic sampling record (including serum collection and fecal sampling dates), vaccinations, disease incidence and treatment, weaning data (weaning date, primary weaning criteria), and any additional notes. Additional information requested included starter feed labels and milk replacer feed labels (if applicable).

Due to the variation observed in the quantity and quality of liquid diet fed per day, the kilograms of protein and fat fed per day were calculated for each calf. Information regarding the amount of liquid diet fed per feeding and the frequency of feedings per day were recorded on the Calf Card, which were used to calculate the total amount of liquid diet fed. For calves fed milk replacer, the percent protein and percent fat were taken from the producer-reported values or the milk replacer label. For calves fed whole or waste milk, percent protein was set at 3.1% and percent fat as 3.8% (as-fed basis). The total amount of protein and fat were calculated, then divided by the number of days fed a liquid diet to determine the kilograms of protein and fat fed per day in the liquid diet.

Additives in the liquid diet were categorized as antibiotics, direct-fed microbials, or other additives, which included fly control, acids, and coccidiostats. Information regarding calf starter

included the percent protein and the age starter was first offered, but starter intake was not recorded.

Biological Sampling

Prior to being enrolled in the study, calves were screened for persistent infection with bovine viral diarrhea virus (BVDV). V-cut ear notchers were used to collect ear notch samples from all calves, which were tested on-farm for BVDV using the IDEXX SNAP ® BVDV Antigen Test (IDEXX, Westbrook, Maine). Calves positive for BVDV were not enrolled in the study. Colostrum samples (40-50 mL) from the first feeding of colostrum administered to the calf were collected in conical screw-top tubes, and then frozen until shipping. Serum samples (5 mL) from calves between 1-7 days of age were collected in serum separator tubes, and samples were centrifuged if possible prior to shipping. Colostrum and serum samples were shipped together on ice to USDA's National Veterinary Services Laboratories in Ames, Iowa. Samples were then accumulated and shipped in bulk to the Saskatoon Colostrum Company in Saskatoon, Saskatchewan. Colostrum and serum samples were tested for IgG concentration using radial immunodiffusion. Blood samples collected within 24 hours of birth or after 7 days of age were excluded from this analysis.

Radial immunodiffusion (RID) was used to measure colostrum and serum IgG. Each agarose plate had 42 wells cut into it. Wells 1-4 and 39-42 were for each of the 4 calibrators, wells 5-9 and 10-14 were for each of the 2 standards that were used to qualify the plate, and wells 15-38 were for test samples. Serial 2-fold dilutions (1/4, 1/8, 1/16, 1/32) of the Bovine IgG Standard (Bovine Serum Calibrator Cat. #4005, Midland BioProducts, Corp.), Reference Bovine Serum (CVB bovine IgG species standard working stock is further diluted 1/4) and Reference Colostrum (diluted 1/15) were prepared in PBS. A 1/4 dilution of test serum and a 1/15 dilution

of test colostrum was prepared using PBS. Two replicates of 4 µL of each dilution of the Bovine IgG Standard were dispensed for the standard curve. Two replicates of 4 µL of the diluted reference colostrum and reference serum and 4 µL of the diluted test sample were dispensed on the plate. The plates were incubated at 20-25ºC for 18-19 hours in a humidified chamber. A plate reader was used to measure and record the ring diameters for the precipitin rings surrounding the wells. Using the results (ring diameters) obtained for each of the 2-fold dilutions of the Bovine IgG Standard and an Excel spreadsheet with calculation formulas, a regression line was generated for each plate for the variables R (ring diameter) versus log10 (concentration). The plate was considered acceptable if the R2 was greater than 0.97 for the standard curve, and the mean values for the reference colostrum and reference serum were the expected values ±10%. Ig concentration for the test sample was determined using the regression line of the Bovine IgG standard obtained for each plate. The diameters were entered into a template where the regression line and Ig concentration (g/L) was calculated.

Fecal samples (50 g) were collected on calves between 2-4 weeks of age in cylindrical screw-top containers. Fecal samples were shipped on ice to USDA Agricultural Research Service's Environmental Microbial Food Safety Laboratory in Beltsville, Maryland. Fecal samples were tested by immunofluorescence microscopy for *Cryptosporidium* and *Giardia*.

Parasite forms were concentrated from feces as previously described (Fayer et al., 2000; Santín et al., 2004). Briefly, 15 g of feces from each specimen cup were mixed with 35-mL of distilled water (dH_2O). The suspension was passed through a sieve with a 45µm pore size screen. The filtrate volume was adjusted to 50 mL with dH_2O and centrifuged at 1800g for 15 min. The pellet was resuspended in a mixture of 25 mL dH_2O and 25 mL CsCl (1.4 g/l) and centrifuged at

300g for 20 min. Supernatant (4 mL), aspirated from each suspension, was washed with dH_2O and the final pellet was examined by microscopy as described below.

A 2 µl of suspension of the pellet was transferred to a well (11 mm diameter) of a 3-well glass microscope slide and 2µl of premixed Merifluor reagent (Meridian Diagnostics, Cincinnati, Ohio) was added. The slide was covered with a 24 mm x 50 mm coverslip and the entire well area was examined and oocysts/cysts counted by fluorescence microscopy at 400X using a Zeiss Axioskop equipped with epifluorescence and an FITC-Texas Red™ dual wavelength filter.

Growth Measurements

Calves were measured approximately every two weeks during the preweaning period to track growth rates. Height/weight tapes from Coburn® (Nasco, Fort Atkinson, WI) were provided for measuring calves. Birth weights were measured either using the operation's standard protocol or a height/weight tape at birth. Hip height and heart girth circumference were measured every two weeks and recorded in centimeters. Heart girth circumference in centimeters was converted to pounds (then converted to kilograms) using the following equation: weight (kg) = weight (lbs) = $((0.0607*(cm(i)^2))+(-6.7854*cm\ (i))+248.777)/2.2$.

Preweaning weight gain was calculated by subtracting the birth weight from the final weight. Average daily gain was calculated by taking the weight gain during the preweaning period divided by the number of days between weight measurements (approximately the preweaning period). Final weights did not always occur at the same time as weaning, though only calves with final weight measurements within 14 days of weaning were included in the analysis. Average daily gain categories were determined by expert opinion based on field experience, with poor ADG <0.64 kg/day, fair ADG 0.64-0.82 kg/day, and excellent ADG >0.82 kg/day.

Environmental Factors

THI data were obtained on a monthly basis by county from the National Oceanic and Atmospheric Administration (NOAA, 2016). THI provides an index that accounts for the effects of temperature and relative humidity, and the equation uses the dry bulb temperature (T, ºF) and the relative humidity (RH). The equation for THI used for this analysis was: THI=T – (0.55 – (0.55*RH/100)*(T – 58). Each calf was assigned a THI for each month during the preweaning period, and then averaged. The average THI for each calf was then categorized according to the thermal neutral zone for a calf as follows: <50, ≥50 and <70, or ≥70.

Elevation data (in meters) were obtained for each county and state from the National Oceanic and Atmospheric Administration (NOAA, 2016).

Statistical Analysis

When each calf was weaned, the Calf Card was mailed to USDA NAHMS. Initial ongoing validation was performed on every calf card as they came in to check accuracy of dates and other information. Data were then entered into SAS (version 9.4; SAS Institute Inc., Cary, NC). Once all Calf Cards were entered, the data were validated again by the NAHMS staff and merged with the results from the colostrum, serum, and fecal testing obtained from the laboratories. Descriptive data were analyzed using the FREQUENCY and MEANS procedures for categorical and continuous variables, respectively. Based on the responses, group size for calves was defined as 1 for individually housed calves.

A model was constructed to determine the factors associated with average daily gain, with operation included as the random variable. Predictor variables were considered for the models based on biological plausibility. To be included in the analysis, only Holstein calves were included, and calves had to have data for all of the variables initially included in the model.

Univariate screening was used to determine which variables to include in the initial model and variables with a P<0.20 were considered for inclusion in the multivariable model. Stepwise backward elimination model selection in PROC MIXED was used to construct the final model, with variables with P<0.05 considered significant, thus included in the model.

RESULTS

Data analysis for ADG included 1,410 Holstein calves. The mean ADG was 0.74 kg/day (SE 0.005), and calves were fed liquid diets an average of 64.7 days (SE 0.5) (Table 6.1). Average birth weight was 43.2 kg (SE 0.137), average final weight was 90.9 kg (SE 0.558), and the average preweaning weight gain was 48.4 kg (SE 0.533). Overall 33.3% of calves had a mean ADG of greater than 0.82 kg/day.

Table 6.1. General growth data for Holstein heifer calves during the preweaning period (n=1,410).

			Percentile				
Variable	**Mean**	**Standard Error**	5th	25th	50th	75th	95th
Birth weight (kg)	43.2	0.14	36.3	39.9	42.6	45.8	52.2
Final weight (kg)	90.9	0.56	59.9	77.6	89.4	101.6	127.0
Preweaning weight gain (kg)	48.4	0.53	20.4	34.9	46.3	58.9	85.5
Age at weaning (days)	64.7	0.48	43.0	56.0	61.0	70.0	100.0
Age at final weight measurement (days)	64.6	0.48	43.0	56.0	61.0	71.0	93.0
Average daily gain (kg/day)	0.74	0.01	0.4	0.6	0.7	0.9	1.1

Initial variables included in the multivariable model for ADG included region, THI category for the preweaning period, dam lactation, number of calves (single vs. twin), direct-fed microbials added to liquid diet, coccidiostats in calf starter, disease status, *Cryptosporidium* status, *Giardia* status, bedding, gender of caretaker, dehorning status, milk pasteurization, birth weight, calf serum IgG, colostrum IgG, protein per day, fat per day, frequency of feedings, and number of vaccines (Tables 6.2 and 6.3). Although the number of calves per pen and milk

delivery system had *P-values* less than 0.05 in the univariate screening, they were excluded from the model due to a strong correlation with protein and fat per day.

Table 6.2. Percent of Holstein heifer calves for all categorical variables initially included in univariate screening for the ADG model, by ADG category (variables in bold denotes a *P-value*<0.05).

				Calves by ADG (%)			
Variable	Variable level	Calves (n)	Calves (%)	Poor <0.64 kg/day	Fair 0.64-0.82 kg/day	Excellent >0.82 kg/day	*P-value*
All calves		1410	100.0%	31.4%	35.4%	33.3%	
Region	West	517	36.7%	34.0%	34.2%	31.7%	**0.095**
	East	893	63.3%	29.8%	36.1%	34.2%	
Herd size (adult cows)	Small (30-99 cows)	194	13.8%	29.4%	38.1%	32.5%	0.611
	Medium (100-499 cows)	408	28.9%	31.4%	37.7%	30.9%	
	Large (500+ cows)	808	57.3%	31.8%	33.5%	34.7%	
ADG THI Categories	<50	647	45.9%	25.3%	33.5%	41.1%	**<0.001**
	≥50 and <70	645	45.7%	34.9%	37.5%	27.6%	
	≥70	118	8.4%	44.9%	33.9%	21.2%	
Dam lactation	First	541	38.4%	36.4%	32.5%	31.1%	**0.000**
	Second	378	26.8%	27.2%	37.6%	35.2%	
	Third+	491	34.8%	28.9%	36.9%	34.2%	
Calving ease	Unassisted	1013	71.8%	29.8%	36.1%	34.1%	0.331
	Easy - 1 person	274	19.4%	36.5%	31.0%	32.5%	
	Difficult = 2+ people	62	4.4%	37.1%	40.3%	22.6%	
	Mechanical/surgical extraction	21	1.5%	28.6%	47.6%	23.8%	
Number of calves born	Single	1360	96.5%	31.2%	34.9%	33.9%	**0.044**
	Twin	50	3.5%	36.0%	48.0%	16.0%	
Milk delivery system	Bottle	280	19.9%	41.4%	36.4%	22.1%	**0.005**
	Bucket/pail	233	16.5%	23.2%	37.3%	39.5%	
	Milk bar	52	3.7%	25.0%	25.0%	50.0%	
	Automated feeder	36	2.6%	33.3%	30.6%	36.1%	
	Bottle & bucket	691	49.0%	32.0%	34.9%	33.1%	
	Other combinations	118	8.4%	22.0%	38.1%	39.8%	
Direct-fed microbials in milk	Yes	244	17.3%	29.1%	37.3%	33.6%	**0.001**
	No	1166	82.7%	31.8%	35.0%	33.2%	

Antimicrobials in milk	Yes	192	13.6%	14.1%	42.7%	43.2%	0.396
	No	1218	86.4%	34.1%	34.2%	31.7%	
Other additives in milk	Yes	784	55.6%	29.6%	35.6%	34.8%	0.709
	No	626	44.4%	33.5%	35.1%	31.3%	
Liquid diet type	Milk replacer	528	37.4%	42.4%	30.7%	26.9%	0.439
	Whole/waste milk	521	37.0%	23.8%	38.6%	37.6%	
	Combination	361	25.6%	26.0%	37.7%	36.3%	
Pasteurization of milk	Yes	348	24.7%	20.7%	36.8%	42.5%	**0.190**
	No	534	37.9%	27.3%	39.1%	33.5%	
	Not applicable	528	37.4%	42.4%	30.7%	26.9%	
Bacterial counts of milk	Yes	139	9.9%	20.9%	38.1%	41.0%	0.423
	No	743	52.7%	25.4%	38.2%	36.3%	
	Not applicable	528	37.4%	42.4%	30.7%	26.9%	
Fly control in calf starter	Yes	213	15.1%	25.8%	35.7%	38.5%	0.937
	No	1197	84.9%	32.3%	35.3%	32.3%	
Coccidiostats in calf starter	Yes	555	39.4%	25.2%	35.0%	39.8%	**0.056**
	No	855	60.6%	35.3%	35.7%	29.0%	
Disease status	1+ disease events	491	34.8%	36.3%	31.8%	32.0%	**<0.001**
	0 disease events	919	65.2%	28.7%	37.3%	33.9%	
Cryptosporidium	Fecal negative	788	55.9%	27.9%	35.7%	36.4%	**0.001**
	Fecal positive	622	44.1%	35.7%	35.0%	29.3%	
Giardia	Fecal negative	980	69.5%	29.1%	35.9%	35.0%	**0.003**
	Fecal positive	430	30.5%	36.5%	34.2%	29.3%	
Bedding	Straw/hay	782	55.5%	26.6%	37.0%	36.4%	**<0.001**
	Shavings	336	23.8%	25.3%	36.3%	38.4%	
	Sand/none	135	9.6%	73.3%	22.2%	4.4%	
	Combination/other	157	11.1%	31.8%	36.9%	31.2%	
Gender of caretaker	Male	909	64.5%	34.4%	33.2%	32.3%	**0.023**
	Female	450	31.9%	25.3%	37.8%	36.9%	
	Both male & female	51	3.6%	29.4%	52.9%	17.6%	
Dehorning	Yes with medications	223	15.8%	24.7%	41.3%	34.1%	**0.116**
	Yes without medications	557	39.5%	27.1%	35.0%	37.9%	
	Not dehorned	630	44.7%	37.5%	33.7%	28.9%	
Ventilation	Natural/outside	1118	79.3%	33.5%	34.4%	32.1%	0.446

Weaning criteria	Positive pressure tubes	141	10.0%	14.9%	35.5%	49.6%	0.271
	Other	151	10.7%	31.1%	42.4%	26.5%	
	Starter intake	44	3.1%	52.3%	22.7%	25.0%	
	Age	764	54.2%	35.9%	35.1%	29.1%	
	Lack of space	84	6.0%	21.4%	29.8%	48.8%	
	Other	25	1.8%	24.0%	24.0%	52.0%	
	Combination	493	35.0%	24.5%	38.5%	36.9%	

The final model included disease status (P<0.001), protein fed in the liquid diet per day (kg/day) (P=0.003), milk pasteurization (P=0.002), addition of direct-fed microbials to the liquid diet (P=0.004), categorized average THI for the preweaning period (P<0.001), dam lactation number (P<0.001), bedding type (P<0.001), singleton vs. twin birth (P=0.008), *Cryptosporidium* status (P=0.003), and *Giardia* status (P=0.026) (Table 6.4).

Table 6.3. Continuous variables initially included in univariate screening for the ADG model, by ADG category (n=1,410) (variables in bold denotes a *P-value*<0.05).

								Average Daily Gain Category						
				Percentiles				Poor <0.64 kg/day		Fair 0.64-0.82 kg/day		Excellent >0.82 kg/day		
Variable	**Mean**	**Std Error**	**5th**	**25th**	**50th**	**75th**	**95th**	**Mean**	**Std Error**	**Mean**	**Std Error**	**Mean**	**Std Error**	***P-value***
Average daily gain (kg/day)	0.74	0.01	0.39	0.59	0.73	0.87	1.08	0.49	0.00	0.73	0.00	0.97	0.01	
Elevation (m)	507.4	11.1	112	258	290	868	1513	442	18.5	555	19.5	517	19.0	0.369
Birth weight (kg)	43.2	0.14	36.3	39.9	42.6	45.8	52.2	42.5	0.21	43.1	0.23	43.8	0.27	**0.009**
Colostrum IgG (g/L)	73.7	0.83	25.7	52.0	72.3	91.5	130.2	72.3	1.48	72.1	1.40	76.6	1.41	**0.150**
Serum IgG (g/L)	21.4	0.27	6.2	14.4	20.8	27.9	38.8	19.9	0.48	21.9	0.46	22.4	0.46	**0.032**
Protein per day (kg/day)	0.2	0.00	0.1	0.2	0.2	0.2	0.4	0.2	0.01	0.2	0.00	0.2	0.01	**0.006**
Fat per day (kg/day)	0.2	0.00	0.1	0.1	0.2	0.3	0.3	0.2	0.01	0.2	0.00	0.2	0.00	**0.011**
Frequency fed	2.7	0.06	1.7	1.9	2.0	2.0	9.0	2.5	0.08	2.7	0.09	3.0	0.11	**0.085**
Amount per feeding (L)	2.6	0.02	0.9	1.9	2.6	3.2	3.8	2.5	0.04	2.6	0.04	2.6	0.04	0.935
Days fed starter	59.5	0.46	37.0	51.0	57.0	66.0	93.0	56.9	0.77	60.0	0.88	61.4	0.68	0.395
Age offered water	6.3	0.34	0.0	1.0	3.0	5.0	34.0	5.8	0.54	7.1	0.60	5.9	0.60	0.879
Starter percent protein	20.3	0.06	17.0	18.0	20.0	22.0	24.0	20.2	0.10	20.4	0.10	20.2	0.11	0.426
Number in group	2.5	0.12	1.0	1.0	1.0	1.0	12.0	2.1	0.20	2.4	0.19	3.1	0.24	**0.145**
Age at weaning	64.7	0.48	43.0	56.0	61.0	70.0	100.0	62.2	0.87	65.5	0.88	66.0	0.72	0.661
Number of vaccines	1.4	0.04	0.0	0.0	1.0	2.0	4.0	1.2	0.06	1.5	0.06	1.6	0.06	**0.079**

After controlling for other independent variables in the model, calves with no disease events gained on average 0.07 kg/day more than calves with one or more disease events. Within the range of observed kg of protein fed per day in the liquid diet, every additional 0.1 kg of protein fed per day equated to 0.02 kg/day of gain. Calves fed milk replacer (0.56 kg/day) gained less than calves fed pasteurized whole/waste milk (0.66 kg/day) and calves fed unpasteurized whole/waste milk (0.63 kg/day). Calves with a direct-fed microbial added to the liquid diet gained 0.06 kg/day less than calves without a direct-fed microbial added. Calves experiencing an average THI less than 50 during the preweaning period (0.66 kg/day) gained more than calves experiencing an average THI between 50 and 69 (0.61 kg/day), or greater than or equal to 70 (0.58 kg/day). Calves from first lactation dams (0.59 kg/day) gained less than calves from second or third or higher lactation dams (0.63 and 0.63 kg/day, respectively). Calves bedded with sand or no bedding (0.48 kg/day) gained less than all other bedding types. Single calves gained 0.07 kg/day more than twins. Calves negative for *Cryptosporidium* at the time of sampling gained 0.03 kg/day more than calves that were positive for *Cryptosporidium*. Calves negative for *Giardia* at the time of sampling gained 0.02 kg/day more than calves that were positive for *Giardia*.

Table 6.4. Results of multivariable modeling of factors associated with ADG for Holstein heifer calves (n=1,410).

Variable	Variable level	Model predicted ADG (kg/day)	Std Error	*F-value*	Final model *P-value*
Dam lactation	First	0.59	0.02	8.52	<0.001
	Second	0.63	0.02		
	Third+	0.63	0.02		
Number of calves	Single	0.65	0.02	7.13	0.008
	Twin	0.58	0.03		
Bedding	Straw/hay	0.67	0.02	7.62	<0.001
	Shavings	0.66	0.03		
	Sand/none	0.48	0.04		
	Combination/other	0.66	0.03		
Milk pasteurization	Pasteurized milk	0.66	0.03	6.52	0.002

	Unpasteurized milk	0.63	0.02		
	Milk replacer	0.56	0.03		
Giardia status	Fecal negative	0.63	0.02	4.98	0.026
	Fecal positive	0.60	0.02		
Cryptosporidium status	Fecal negative	0.63	0.02	8.77	0.003
	Fecal positive	0.60	0.02		
Direct-fed microbials in milk	Yes	0.58	0.03	8.18	0.004
	No	0.65	0.02		
Disease status	1+ disease events	0.58	0.02	34.62	<0.001
	0 disease events	0.65	0.02		
THI	<50	0.66	0.02	14.72	<0.001
	≥50 and <70	0.61	0.02		
	≥70	0.58	0.03		
Protein per day (kg/day)		0.22	0.08	8.77	0.003

DISCUSSION

The results of this study showed that ADG of dairy heifer calves during the preweaning period was influenced by many factors, including disease, protein per day fed in the liquid diet (kg), addition of direct-fed microbials to the liquid diet, milk pasteurization, THI for the preweaning period, dam lactation, bedding type, the number of calves born (single vs. twin), *Cryptosporidium* status, and *Giardia* status. As expected, calves with one or more disease events during the preweaning period gained less than calves with no disease events. Previous research has also shown a negative relationship between disease and growth (Virtala et al., 1996; Donovan et al., 1998). The two most commonly reported clinical signs of disease in this study were digestive and respiratory signs. Disease during the preweaning period can impact ADG by nutrient loss from the diet via diarrhea, diversion of energy to the immune system and away from growth, and suppressed appetite and feed intake. Disease events were self-reported by producers for this study, and it is possible that some operations were more vigilant about detecting and reporting disease than others. Therefore, the real impact of disease on ADG was probably greater than the results of this study indicate. Ensuring calves are fed the appropriate amount of high

quality colostrum immediately after birth for adequate passive transfer of immunity, housing calves in a clean environment, and providing proper nutrition can all help reduce the incidence of disease in calves (LeBlanc et al., 2006), thus improving ADG.

Nutrition during the preweaning period is critical for growth, with both the quantity and the quality of the liquid diet having significant impacts (Drackley, 2008). In one study, calves allowed to consume milk ad libitum consumed twice as much milk and gained four times as much compared with restricted-fed calves who also displayed signs of hunger (De Paula Vieira et al., 2008). Increasing the amount of milk fed during the preweaning period can also increase future milk yield (Van Amburgh et al., 2014), as well as decrease the time to first calving (Curtis, 2015). According to the NRC energy requirements for calves (NRC, 2001), the metabolizable energy (ME) required for maintenance of a 45-kg calf under thermoneutral conditions is 1.75 Mcal/day, which equates to about 2.5 L of whole milk or 3.0 L of an average milk replacer (20% protein, 20% fat), since most milk replacers have lower levels of fat compared with milk (Drackley, 2008). Protein requirements are determined by the desired rate of growth (Drackley, 2008). Since calves in this study were fed varying amounts of liquid diets of differing quality, the average amount of protein and fat fed to the calf per day were used in the ADG model. The protein and fat per day (kg) were highly correlated, with only protein per day staying in the final model. The results of this study showed that ADG increased with greater amounts of protein fed per day. Similarly, Li et al. (2008) showed that calves fed a high protein diet had greater ADG than calves fed mid or low protein diets. Increasing protein in the diet appeared to have a positive linear relationship with body weight gain (Blome et al., 2003). Calves fed a higher plane of nutrition were able to convert the additional nutrients into lean tissue at high efficiency (Liang et al., 2015b). Increasing the amount of protein in the liquid diet,

either by increasing the overall amount of liquid diet fed or increasing the concentration of protein in the liquid diet, leads to improved ADG in dairy heifer calves during the preweaning period.

In this study, calves fed milk replacer gained significantly less than calves fed pasteurized or unpasteurized milk. A survey of on-farm pasteurizers showed that while waste milk composition is highly variable, concentrations of protein and fat are greater than conventional milk replacers (Jorgensen et al., 2006). Concerns with feeding waste milk include inconsistent composition, bacterial contamination, and antimicrobial residues. A controlled experiment comparing calves fed pasteurized waste milk versus a 20:20 conventional milk replacer found that calves fed waste milk had higher weaning weights, higher ADG, as well as lower morbidity and mortality (Godden et al., 2005). The higher fat content of milk can have a detrimental effect on starter intake, potentially reducing ADG, as seen by Hill et al. (2009). Not all milk replacers are created equally, and supplementing milk replacers with amino acids and fatty acids can improve ADG (Hill et al., 2007). Perhaps more important than the source of the liquid diet is the quantity and the quality of the diet administered to the calf. While the quality of milk replacers in terms of percent fat and protein were accounted for in the model, the sources of the fat and protein were not controlled for, nor were additional supplements.

In this study, the addition of direct-fed microbials to the liquid diet resulted in a lower ADG compared with not adding direct-fed microbials. Direct-fed microbials, or probiotics, are non-pathogenic microbial species that are added to the diet to improve gastrointestinal flora (BAMN, 2011). While several studies have shown improved growth rates when feeding direct-fed microbials (Abe et al., 1995; Timmerman et al., 2005; Adams et al., 2008), other studies have shown that direct-fed microbials had no effect on growth or health (Jenny et al., 1991; Morrill et

al., 1995; Abu-Tarboush et al., 1996; Higginbotham et al., 1998). Direct-fed microbials may be most important for calves exposed to pathogens or environmental challenges that lead to stress, disrupting the intestinal flora (BAMN, 2011). Because of this, perhaps calves that were fed direct-fed microbials in this study were already experiencing stress, which is why the producer decided to add direct-fed microbials to the diet. The resulting lower ADG detected in this study associated with feeding direct-fed microbials might actually be detecting other challenges on the operation.

Increasing the plane of nutrition during the preweaning period not only impacts ADG, but it can also lead to better overall immunity. Until recently, few studies evaluating the effects of nutrition on disease had been conducted, though previous work has shown that calves fed less energy and protein than necessary for growth also have higher death losses (Goff, 2006). One study found that the plane of nutrition may modulate functions associated with cell-mediated immune responses, though this was conducted via ex vivo cell function assays (Nonnecke et al., 2003). In a controlled trial comparing a low plane of nutrition with a high plane of nutrition during the preweaning period, calves were subsequently challenged with *Mannheimia haemolytica* and a combined bovine herpesvirus-1 and *M. haemolytica* challenge post weaning. Calves fed a low plane of nutrition preweaning responded more severely to the combined viral and bacterial challenge postweaning (Sharon et al., 2015a; Sharon et al., 2015b). Lower planes of nutrition during the preweaning period appeared to increase the risk of respiratory disease one month after weaning, indicating that early life nutrition can influence resistance to and pathology of disease (Sharon et al., 2015a; Sharon et al., 2015b). Another study found that calves fed a high plane of nutrition during the preweaning period had a greater acute phase response to an opportunistic bacterial enteric infection compared with calves fed a low plane of nutrition (Liang

et al., 2015a). Nutrition of calves during the preweaning period is important for immune function and disease susceptibility, in addition to improving growth rates.

Environmental factors were evaluated for influences on ADG, and the average THI during the preweaning period was associated with growth. Calves experiencing an average THI during the preweaning period of less than 50 gained more than calves experiencing an average THI of 50 to 69 or 70 or more. Previous research has shown that calf growth is negatively affected by periods of heat stress, with lower starter consumption and lower body weights at weaning (Broucek et al., 2009). Decreased blood flow to the digestive tract during periods of heat stress led to decreased absorption of nutrients, and decreased feed intake (Beede and Collier, 1986). Any deviation from the thermoneutral zone for a calf causes some degree of thermal stress (Roland et al., 2016), yet calves seem better able to handle cold stress than heat stress, if provided enough nutrition. Maintenance requirements for calves outside of the thermoneutral zone increase (Drackley, 2008), though an increase in starter intake can help the calf meet maintenance requirements. Nonnecke et al. (2009) showed that calves raised in a cold environment had similar gains to calves raised in a warm environment, but the cold calves consumed more starter. When comparing ADG over different seasons, calves in the winter tended to gain the most and calves in the summer tended to gain the least, providing further support for calves adjusting better to cold than heat stress (Place et al., 1998). Heifers that experience heat stress have increased metabolic requirements, yet this is compounded by decreased appetite and decreased feed intake (West, 2003). This study was unable to quantify starter intake, but it is highly likely that calves raised during colder periods consumed more starter intake than calves raised in the thermoneutral zone or in hot periods, accounting for their increased ADG.

Previous research has shown a link between heat stress during the dry period and subsequent calf growth. While not included in the model due to a strong correlation between THI of the month prior to calving (dry period) and THI during the preweaning period, there was an association between ADG and THI during the dry period. Calves from dams that experienced a lower THI during the dry period had greater ADG than calves from dams experiencing a high THI. This study did not ask about heat abatement techniques used by operations for dry cows, only relying on county level THI data on an average monthly basis. Dahl et al. (2016) found that calves from dams that were cooled during the dry period had higher birth weights and better growth compared with calves from dams that were not cooled during periods of heat stress. Dry matter intake for cows and placental development were negatively affected by heat stress (Dahl et al., 2016). Calves born to cows that were heat stressed during late gestation had permanent metabolic shifts associated with greater fat accumulation and less lean growth (Tao and Dahl, 2013). Similarly, calves born to cows not heat stressed during late gestation consumed more starter and gained more during the preweaning period compared to calves that were heat stressed in utero (Monteiro et al., 2016). Mitigating the effects of heat stress during the dry period may not only improve subsequent milk production, but also improve growth in the calves.

The bedding type used was associated with ADG in this study, with calves bedded with sand or no bedding gaining significantly less than all other bedding types used. It is interesting that sand bedding was not a good choice for preweaned calves but appears to be the best bedding for cows (Lombard et al., 2010; Andreasen and Forkman, 2012). When given a choice, calves preferred sawdust over concrete, even if the sawdust was wet (Camiloti et al., 2012). Another study showed that calves preferred sawdust over all other bedding types (Worth et al., 2015). One study showed that calves bedded with straw gained more than calves bedded with sand (Hill

et al., 2011). While Panivivat et al. (2004) found no differences in growth between different bedding types, calves housed on sand had more scour treatments and were scored as dirtiest compared to all other bedding types. Calves with more lying bouts tended to have higher gains compared to calves with fewer lying bouts (Mogensen et al., 1997). By providing calves with a more comfortable environment with bedding substrates other than sand or no bedding, calves likely spend more time lying down, thus improving their growth.

Calves from single births gained more during the preweaning period than calves from twin births. Twin calves generally have significantly lower birth weights (Kertz et al., 1998; Hossein-Zadeh, 2010). Birth weight was included in the initial model for ADG, yet did not remain in the final model. The average birth weight for single calves was 43.3 kg (SE 0.14), and average birth weight for twin calves was 39.2 kg (SE 0.74). Research in beef cattle has shown that twin calves have a lower birth weight and lower gains than single calves (Gregory et al., 1996). Another study showed that birth weight was a predictor for growth rates in calves (Lundborg et al., 2003). Although the calculation for ADG accounts for birth weight, it appears that twin calves are not able to maintain the same growth rate during the preweaning period as single calves.

Dam lactation was associated with ADG, with calves from first calf heifers having significantly lower ADG compared with second or third or higher lactation dams. Since birth weight is positively associated with parity (Linden et al., 2009), larger cows tend to have larger calves (Swali and Wathes, 2006). Since heifers are still growing during their first pregnancy, they typically have smaller calves at birth compared with calves from second or higher lactations cows (Losinger and Heinrichs, 1997). Calves with lower birth weights tended to gain less throughout the preweaning period and the first lactation (Swali and Wathes, 2006).

Calves fecal positive for *Cryptosporidium* and calves fecal positive for *Giardia* at the time of fecal sampling gained significantly less than calves negative for *Cryptosporidium* or *Giardia*. Individual calf fecal samples were collected only once between 2-4 weeks of age, so some of the calves that were not shedding *Cryptosporidium* or *Giardia* at the time of sampling might have been positive at some point during the preweaning period, likely decreasing the observed impact of *Cryptosporidium* and *Giardia* on ADG. *Cryptosporidium* infections occur early during the preweaning period (Santín et al., 2004), typically between 1-3 weeks of age (average: 16 days of age) (O'Handley et al., 1999). A longitudinal study showed the prevalence of *Cryptosporidium* peaked at 2 weeks of age (Santín et al., 2008). *Cryptosporidium* infections cause damage to the brush border of enterocytes, leading to decreased absorptive capacity and osmotic diarrhea (Constable, 2014). Decreased absorption and diarrhea lead to decreased nutrient absorption and decreased ADG. Infections with *Cryptosporidium* can also be accompanied by depression, weakness, and anorexia. *Giardia* infections generally occur later in a calf's life (approximately 4-5 weeks of age) (Santín et al., 2009), and are also associated with diarrhea (O'Handley et al., 1999). *Cryptosporidium* is considered endemic in dairy herds in the U.S. (Garber et al., 1994), making on-farm hygiene important in disease control.

Since this was a nationwide field study, there were some limitations in study design. More producers were expected to participate in the study than actually did, making this a convenience sample rather than a nationally representative sample of dairy heifer management across the U.S. dairy industry. Data collected on farm included self reporting on the Calf Card, with some operations potentially reporting standard operating procedures and not necessarily individual calf level data. One important piece of information that is associated with ADG is starter intake. This study did not collect information on individual calf starter intake due to the

intense resources that would be needed to capture this information on a routine and consistent basis.

These results highlight the importance of feeding an appropriate quantity and quality of a liquid diet, keeping calves free from disease and comfortable, and mitigating the effects of temperature and humidity during the preweaning period, on ADG.

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CHAPTER VII: MANAGEMENT OF PREWEANED BULL CALVES ON DAIRY OPERATIONS

INTRODUCTION

Significant amounts of research have been conducted regarding the care and management of neonatal dairy calves over the past several decades, including proper colostrum management and pain mitigation for routine procedures. Since dairy heifer calves are the future of the dairy operation, the focus has been on dairy heifer calves. Most of the best practices developed for heifer calves can also be applied to dairy bull calves.

Colostrum quality, quantity, timing of feeding, and cleanliness are the four most important factors related to colostrum management for adequate passive transfer of immunity (McGuirk and Collins, 2004). The prevalence of failure of passive transfer (FPT) has been evaluated over the years in dairy heifer calves (USDA, 1993; Beam et al., 2009), and specific risk factors for FPT have been identified. To our knowledge, no research regarding colostrum management in bull calves has been conducted to see if recommended colostrum practices for heifers are being followed for bull calves. Regardless of the intended use of the bull calves, they need colostrum to prevent infections during the first few weeks of life (Weaver et al., 2000). This becomes especially important for bull calves that are sold, transported, and comingled with other calves at a young age.

Dehorning is routinely performed on dairy calves to reduce the risk of injury to handlers and other cattle. No matter what method is used, dehorning is a painful experience for calves. However, dehorning at a young age and using analgesics and/or anesthetics can help mitigate this pain (Graf and Senn, 1999; Grondahl-Nielsen et al., 1999; K.J. Stafford and Mellor, 2005).

Castration is another routine husbandry procedure commonly performed on bull calves to reduce unwanted behaviors and modify carcass quality. All physical methods of castration cause pain in cattle, which can be alleviated with the use of analgesics and/or anesthetics (K. Stafford and Mellor, 2005). Since dairy bull calves are often sold by the operation of origin at a young age, it is currently unknown if dairy bull calves are dehorned or castrated prior to leaving, what methods are used, and if analgesics and/or anesthetics are used.

The objectives of this study were to survey management practices applied to dairy bull calves on the operation of birth, and to compare these practices to those used on dairy heifer calves on the same operations.

MATERIALS AND METHODS

The NAHMS Dairy 2014 study was designed to represent at least 70% of dairy operations and dairy cattle in the United States. The National Agricultural Statistical Service (NASS) "Cattle Report" was used to determine which states to include (USDA, 2013). Seventeen states were selected for inclusion in the study, representing 80.3% of dairy cows and 76.7% of dairy operations. States and regions included in the study were: west: California, Colorado, Idaho, Texas, Washington; east: Indiana, Iowa, Kentucky, Michigan, Minnesota, Missouri, New York, Ohio, Pennsylvania, Vermont, Virginia, and Wisconsin. NASS provided a sampling frame list and selected a stratified random sample of dairy operations within each state to participate in the study, with 3,000 operations with 30 or more cows eligible to participate. NASS provided operation-level weights, which were used to account for selection criteria and study nonresponse. National estimates of the US dairy industry were generated using the weights.

Dairy operations were categorized by herd size (small: 30 to 99 cows; medium: 100-499 cows; and large: 500 or more cows). The General Dairy Management Questionnaire (GDMQ) was the first survey, completed by NASS enumerators with dairy producers during visits to dairy operations in January 2014 (phase I). The GDMQ survey included 171 questions regarding dairy cow and heifer inventory, biosecurity practices, preweaned heifer management (including colostrum management), weaned and pregnant heifer management, cow management, manure management, and the use of veterinarians. Operations that completed phase I and had 30 or more cows were eligible to continue the study. Phase II included the Veterinary Services (VS) Visit Survey, conducted during on-farm visits by USDA:VS and state animal health staff from March to July 2014. The VS survey included 144 questions regarding milk quality and milking procedures, personnel training, reproduction management, surgical procedures (including dehorning and castration), hoof health and lameness, beef quality assurance, disease preparedness, morbidity and mortality, and drug use and residue avoidance. Data for heifer calves were obtained from the GDMQ and the VS surveys for all operations that completed the bull calf survey.

All operations that participated in phase II were invited to participate in the longitudinal heifer calf study. The heifer calf study began in March 2014 and concluded in September 2015. Each operation was instructed to enroll 24 heifer calves over a one-year period, or an average of 2 calves per month. Due to fewer operations participating than originally planned, the number of calves that could be enrolled per operation was increased to 48-60. Each calf was followed from birth to weaning, with information captured on the Heifer Calf Health Card. Colostrum samples, serum samples, and fecal samples were collected and tested for each enrolled calf.

Operations that participated in the longitudinal calf study were eligible to complete the Bull Calf Questionnaire, a nine-question survey asking about the management of bull calves on the operation. Questions on the survey asked specifically about bull calf management, and all questions were repeated with the modification of changing 'heifer' to 'bull' on both the GDMQ and the VS survey, which asked about heifer calf management. Questions asked about the number of bull calves born on the operation, stillbirths, colostrum management, dehorning, and leaving the operation.

Five operations that completed the bull calf survey were not part of the NAHMS study, and no data from the GDMQ or VS surveys were available for those operations. Data from the longitudinal heifer calf study were used to determine practices related to colostrum management and dehorning being used on heifer calves on those five operations, and those data were then used to compare to results from the bull calf survey. Information on castration was not available for these 5 operations.

Data from the GDMQ survey were entered and validated by NASS using SAS (version 9.4; SAS Institute Inc., Cary, NC). Once all of the data were collected from all 17 states, the complete dataset was validated a second time by the NAHMS staff. Data from the VS survey, the heifer calf study, and the bull calf survey were entered and validated by the NAHMS staff using SAS. Descriptive data were analyzed using the FREQ and the MEANS procedures of SAS for categorical and continuous variables, respectively. Except for the five operations not part of the national study, responses on the GDMQ and VS surveys related to heifer calf management were compared to responses on the bull calf survey for all operations that completed the bull calf survey.

RESULTS

General Results

The bull calf survey was completed by 42 operations out of 104 operations eligible to participate, for a response rate of 40.4%. Overall, these 42 operations represented 10 states (CO, IA, MI, MN, NY, OH, PA, VT, WA, WI). Table 7.1 shows complete demographic information for the bull calf survey.

Table 7.1. Percent of operations for the bull calf survey, by region and herd size (n=42 operations).

Variable	Level	Percent Operations	Number of Operations
Region	West	19.0%	8
	East	81.0%	34
Herd size	Small (30-99 cows)	16.7%	7
	Medium (100-499 cows)	35.7%	15
	Large (500+ cows)	47.6%	20

The percent stillbirths in bull calves was 7.4% (SE 0.7), while the percent stillbirths was 5.8% (SE 0.6) for all calves (heifer and bull calves) on the 42 operations. The majority of operations sold bull calves prior to weaning (97.6%) and these calves left the operation at an average of 7.6 days of age (SE 1.9). Overall 2.4% (SE 0.5) of bull calves died prior to leaving the operation (excluding stillbirths).

Colostrum Management

Regarding colostrum management, 96.3% (SE 2.4) of bull calves received colostrum. Of the bull calves that received colostrum, 1.5% (SE 0.9) of bull calves received colostrum by suckling the dam only, compared with 0.0% of heifer calves. Bull calves received colostrum within 4.3 hours (SE 0.5) following birth, compared to 2.9 hours (SE 0.4) in heifer calves. Bull calves were fed an average of 3.1 L (SE 0.1) of colostrum at the first feeding, 1.7 L (SE 0.2) in all subsequent feedings, for a total of 4.8 L (SE 0.3) of colostrum within the first 24 hours.

Heifer calves on the same 42 operations were fed an average of 2.9 L (SE 0.2) of colostrum at the first feeding, 2.5 L (SE 0.3) in all subsequent feedings, for a total of 5.4L (SE 0.3) of colostrum within the first 24 hours (Table 7.2).

Table 7.2. Colostrum management for bull and heifer calves on the 42 participating operations (for calves that were handfed colostrum).

	Bull Calves		Heifer Calves	
Parameter	Pct/Mean	Std Error	Pct/Mean	Std Error
Percentage of calves that received colostrum	96.3	2.4	100.0	(--)
Percentage: hand feeding only	95.4	1.8	88.9	4.8
Percentage: hand feeding and suckling	3.1	1.3	11.1	4.8
Percentage: suckling only	1.5	0.9	0.0	0.0
Timing to first colostrum feeding (hours)	4.3	0.5	2.9	0.4
Amount of colostrum at first feeding (L)	3.1	0.1	2.9	0.2
Amount in all subsequent feedings (L)	1.7	0.2	2.5	0.3
Total colostrum in first 24 hours (L)	4.8	0.2	5.4	0.3

Dehorning Practices

The majority of operations (78.6%) did not dehorn bull calves, leaving only 9 operations that dehorned bull calves. A hot iron was used on 66.7% (6 operations) of operations that dehorned bull calves, and was used on 70.3% (SE 18.8) of bull calves on those operations. The average age of dehorning with a hot iron was 19.8 days of age (SE 6.3) and 1 of the 6 operations used any analgesics or anesthetics for dehorning. Caustic paste was used on 22.2% (2 operations) of operations that dehorned bull calves, and was used on 100.0% of bull calves on those operations. The average age of dehorning with caustic paste was 0.5 days of age (SE 0.5) and no operations used analgesics or anesthetics. A tube, spoon, or gouge was used on 11.1% (1 operation) of operations that dehorned bull calves, and was used on 100.0% of bull calves on that operation. The average age of dehorning with a tube, spoon, or gouge was 16.0 days of age (SE 0) and no analgesics or anesthetics were used on this operation. Bull calves were not dehorned using any other methods, including saws, wires, or Barnes. The total number of bull calves

dehorned on operations that dehorned bull calves was 80.2% (SE 13.1), and ranged from 7.0 to 100.0% of bull calves (Table 7.3).

The majority of operations (88.1%) dehorned heifer calves (37 operations). A hot iron was used on 81.1% (30 operations) of operations that dehorned heifer calves, and was used on 89.7% (SE 3.7) of heifer calves on those operations. The average age of dehorning with a hot iron was 7.1 days of age (SE 1.0). Analgesics or anesthetics for dehorning with a hot iron were used on 9 of the 30 operations (30.0%). Caustic paste was used on 21.6% (8 operations) of operations that dehorned heifer calves, and was used on 56.0% (SE 11.9) of heifer calves on those operations. The average age of dehorning with caustic paste was 1.6 days of age (SE 0.3) and none of the operations used analgesics or anesthetics. A tube, spoon, or gouge was used on 8.1% (3 operations) of operations that dehorned heifer calves, and was used on 82.3% (SE 16.2) of heifer calves on those operations. The average age of dehorning with a tube, spoon, or gouge was 11.3 days of age (SE 6.4) and analgesics or anesthetics were used on 2 of the 3 operations. A saw, wire, or Barnes was used on 13.5% (5 operations) of operations that dehorned heifer calves, and was used on 43.0% (SE 16.2) of heifer calves on those operations. The average age of dehorning with a saw, wire, or Barnes was 33.5 days of age (SE 10.9) and no analgesics or anesthetics were used. On operations that dehorned heifer calves, 100.0% of heifer calves on those operations were dehorned (Table 7.3).

Table 7.3. Dehorning practices for bull and heifer calves on the 42 participating operations.

Parameter	Level	Percent of operations (number of operations)	Percent of calves	Age (days)	Use analgesics/ anesthetics
Bull Calves					
Dehorn	Yes	21.4% (9)		15.1 (SE 4.9)	11.1%
Method of dehorning	Hot iron	66.7% (6)	70.3% (SE 18.8)	19.8 (SE 6.3)	16.7%
	Caustic paste	22.2% (2)	100.0% (SE --)	0.5 (SE 0.5)	0.0%
	Tube/spoon/gouge	11.1% (1)	100.0% (SE --)	16.0 (SE 0.0)	0.0%
	Saws/wire/Barnes	0.0% (0)			
	Other	0.0% (0)			
Total number of calves dehorned			80.2% (SE 13.1)		
Heifer Calves					
Dehorn	Yes	88.1% (37)		8.5 (SE 1.3)	23.9%
Method of dehorning	Hot iron	81.1% (30)	89.7% (SE 3.7)	7.1 (SE 1.0)	30.0%
	Caustic paste	21.6% (8)	56.0% (SE 11.9)	1.6 (SE 0.3)	0.0%
	Tube/spoon/gouge	8.1% (3)	82.3% (SE 16.2)	11.3 (SE 6.4)	66.7%
	Saws/wire/Barnes	13.5% (5)	43.0% (SE 16.2)	33.5 (SE 10.9)	0.0%
	Other	0.0% (0)			
Total number of calves dehorned			100.0% (SE --)		

Castration Practices

Of the 42 participating operations, 6 operations either didn't complete the VS survey, or did not answer the castration questions. The majority of operations that responded (72.2%; 26/36) did not castrate bull calves while they were on the operation. Of the 27.8% of operations that castrated bull calves, 70.0% (n=7) used a band. The average age of castration on operations that banded bull calves was 6.3 weeks (SE 0.9) and only 1 of the 7 (14.3%) used analgesics or anesthetics. A knife was used on 30.0% of operations that castrated bull calves. The average age of castration on operations that used a knife was 14.7 weeks (SE 4.8) and none of these operations used analgesics or anesthetics for castration. No operations used a Burdizzo or other methods of castration (Table 7.4).

Table 7.4. Castration practices for the 36 participating operations.

Parameter	Level	Percent of Operations (number of operations)	Age (weeks)	Use analgesics/anesthetics
Castrated	Yes	27.8% (10)	8.8 (SE 1.9)	10.0%
Method of castration	Band	70.0% (7)	6.3 (SE 0.9)	14.3%
	Knife	30.0% (3)	14.7 (SE 4.8)	0.0%
	Burdizzo	0.0% (0)		

DISCUSSION

This study was one of the first attempts to summarize the management of bull calves on U.S. dairy operations. Dairy bull calves are sometimes seen as a byproduct of the dairy industry. Because of this, some fear that less emphasis is placed on the care and management of dairy bull calves since they will not produce milk, and therefore money, for the operation in the future. The results of this study did find differences in how bull calves were managed compared to heifer calves on the same operations related to colostrum management and dehorning practices.

Regarding colostrum management, 96.3% of bull calves received colostrum, although all bull calves should receive colostrum. One operation reported that only 9% of bull calves received colostrum, setting these calves up for a high risk of infection. Calves are born agammaglobulinemic, making colostrum critical for calves to resist infections in the first few weeks of life (Gulliksen et al., 2008). Overall 1.5% of bull calves received colostrum by suckling their dam only, with one operation reporting that 30% of bull calves received colostrum by suckling only. Hand-feeding calves colostrum, rather than allowing them to suckle their dam, enables producers to more closely monitor the timing, amount, and quality of the colostrum fed, and reduces the risk of failure of passive transfer (Franklin et al., 2003). No heifer calves received colostrum by suckling their dam only for participating operations, indicating that heifer calves are treated differently than bull calves on those operations.

The timing to colostrum feeding and the amount fed are critical components to ensure adequate passive transfer of immunity (Godden, 2008). Additionally, failure of passive transfer was shown to be a major risk factor for poor veal calf welfare, with 78% of calves in veal facilities having inadequate immunity (Stull and McDonough, 1994). Bull calves received their first feeding of colostrum an average of 4.3 hours after birth, ranging from 1-15 hours, putting some calves at risk of poor absorption of immunity due to delayed colostrum feeding. Heifer calves on those same operations received colostrum an average of 2.9 hours after birth, ranging from 0-12 hours. These results showed that generally heifer calves received colostrum sooner than bull calves on those operations. While bull calves were actually fed a greater amount of colostrum at the first feeding than heifer calves (3.0 L vs. 2.8 L, respectively), bull calves were fed less in subsequent feedings for a lower total volume of colostrum fed in the first 24 hours than heifer calves (4.8 L vs. 5.4 L, respectively). Calves should be fed at least 10% of body weight of colostrum at the first feeding, which equates to about 4.0 L for the average size Holstein (Godden, 2008). This standard was not met for bull calves or heifer calves on these operations, and increasing the volume of colostrum fed at the first feeding is recommended.

The percentage of stillbirths reported in bull calves (7.4%) was slightly higher than the percentage of stillbirths in all calves on those operations (5.8%). The national estimate for stillbirth percentage from the overall Dairy 2014 study was 5.6%, indicating that the subset of operations that completed the bull calf survey had a similar incidence of stillbirths in all calves to the national estimate (USDA, 2016b). In the GDMQ survey, this question asked about all calves, not specifically heifer calves, so a direct comparison cannot be made regarding stillbirths between bull calves and heifer calves. Previous research has shown that bull calves had higher rates of stillbirths than heifer calves (Meyer et al., 2001; Lombard et al., 2007). Overall, an

average of 2.4% of bull calves died prior to leaving the operation. For preweaned heifer calves in the NAHMS Dairy 2014 study, the mortality rate for preweaned heifers was 6.4% (USDA, 2016c). The mortality rate for heifer calves accounts for the entire preweaning period, whereas most bull calves left the operation by one week of age, so it is difficult to compare death rates between bull and heifer calves.

The majority of operations sold bull calves prior to weaning (97.6%), at an average age of 7.6 days, with 48.5% of these operations selling their bull calves through an auction. The national estimate from the Dairy 2014 study showed that 90.2% of operations sold bull and steer calves, with no differences across herd sizes and almost two-thirds of operations (61.8%) sold bull calves through auctions (USDA, 2016b). Transportation early in life can lead to stress due to handling, particularly during loading and unloading, as well as thermal stress from adverse environmental conditions (Trunkfield and Broom, 1990; Stull and Reynolds, 2008). Calves are especially sensitive to cold temperatures during transport (Eicher, 2001). This stress can impede immunocompetence, particularly in young calves without a developed immune system (Hulbert and Moisá, 2016). Gentle handling by trained drivers and handlers can help reduce the stress associated with transport (Stull and Reynolds, 2008; Grandin and Shivley, 2015). Bull calves are typically sold to beef feeders to be raised for beef, with a small number of bull calves sold for veal production.

The majority of operations (78.6%) did not dehorn bull calves, probably in part because they left the operation at a young age. Dehorning is especially important for dairy bull calves that will be raised for meat since significant hide damage and carcass losses can be attributed to bruising from horns (Marshall, 1977). Hot iron was the most commonly used method (66.7% of operations), followed by caustic paste (22.2%), and lastly tube/spoon/gouge

(11.1%). Analgesics or anesthetics were not routinely used, with only one of the 9 operations that dehorned bull calves, using them for dehorning bull calves. Pain mitigation was only used on the operation that dehorned using a hot iron. When ranked according to stress, dehorning using a hot iron was considered least stressful compared to other methods, and the use of analgesics and/or anesthetics reduced pain and distress for all methods (Graf and Senn, 1999; K.J. Stafford and Mellor, 2005). The majority of those same operations (88.1%) dehorned heifer calves, and 23.9% of operations that dehorned heifer calves used pain mitigation. National estimates from Dairy 2014 study were slightly more optimistic, with pain mitigation being used on 28.2% of the 94.3% of operations that dehorned heifer calves (USDA, 2016c). Bull calves were dehorned at an older age (15.1 days) than heifer calves on the same operation (8.5 days). The overall age at dehorning heifer calves from the Dairy 2014 study was 9.2 days, similar to heifer calves on the operations in this study (USDA, 2016c). The age of dehorning is considered by some to be of more concern than the method used, with dehorning at a younger age being better for animal welfare (Stookey, 1994; Stull and Reynolds, 2008). Some countries now require pain relief for painful procedures, with options currently available to address acute and chronic pain associated with dehorning (Stock et al., 2013). Not only does the use of pain relief reduce the distress for the calves, it can make the procedure easier for the person performing it by reducing the amount of struggling by the calf (Grondahl-Nielsen et al., 1999). Based on the results of this study, more producer education regarding pain relief options in cattle is warranted, or the use of polled cattle genetics needs to be further utilized.

Most operations did not castrate bull calves (72.2%). Of those that did castrate, banding was the most commonly used method (70.0%), followed by knife (30.0%). This was similar to the results from the Dairy 2014 study, with 35.5% of all operations castrating bull calves, with

banding being used most common method (72.5% of operations), followed by knife (20.2%), and lastly Burdizzo (7.3%)(USDA, 2016c). Due in part to public concern about the pain associated with castration (Weary and Fraser, 2008), many studies have been done comparing different castration techniques. While all methods cause acute pain, banding causes the most chronic pain (Robertson et al., 1994; Molony et al., 1995). Pain associated with castration can decrease growth and negatively impact average daily gain in cattle (Fisher, 1996). Pain mitigation can help alleviate the pain and distress associated with castration, and there use is supported by the American Veterinary Medical Association (AVMA, 2014). Analgesics or anesthetics were not commonly used for castration and pain mitigation was only used for banding. Only 4.0% of operations in the Dairy 2014 study reported using analgesics or anesthetics for castration, and also only for banding (USDA, 2016c). Local anesthetics can alleviate acute distress associated with castration, but a multimodal approach combining local anesthetics and a non-steroidal anti-inflammatory medication have shown the greatest impact on cortisol responses (Coetzee, 2011; Coetzee, 2013). This survey only asked if analgesics and/or anesthetics were used for castration, so further evaluation about pain mitigation strategies being used on-farm could not be assessed. Regardless, pain relief should be used on more operations for a procedure that is known to cause pain (K. Stafford and Mellor, 2005), and pain relief should be a target for producer education programs.

There were limitations to the study. Data for this analysis came from several different parts of the USDA Dairy 2014 Study, which were completed at different points in time and by different numbers of operations. Since the bull calf survey was completed after the GDMQ and the VS surveys, it is possible that differences found were a reflection of management changes on the operation, and not necessarily differences between the management of bull calves and heifer

calves. Only operations that participated in the longitudinal dairy heifer calf study were eligible to complete the bull calf survey, limiting the possible responses to 104 operations in a convenience sample. Of those, only 42 completed the bull calf survey. Data were self-reported by producers, with some responses limited to record-keeping on the farm (for example, number of bull calves born on the operation in 2014). While the overall number of completed bull calf surveys was lower than desired, the responses represented diversity in the dairy industry, including 10 states and operations of all sizes.

Overall, bull calves were managed differently from heifer calves on those same operations regarding colostrum management and dehorning practices. Bull calves were fed colostrum later and a lower total amount in the first 24 hours compared to heifer calves. Most operations sell bull calves, and the calves leave the operation at about one week of age. The majority of operations are not dehorning or castrating bull calves prior to leaving. On the operations that do dehorn or castrate bull calves, pain management is not frequently used. Operations that are using methods of dehorning and castration that have been shown to cause the most pain, including surgical techniques, are not using any pain relief for these procedures. These results highlight the need to evaluate passive transfer in bull calves to monitor colostrum management practices and educate producers and veterinarians in the value of using analgesics or anesthetics for painful procedures in bull calves.

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CHAPTER VIII: CONCLUSIONS

VETERINARY CURRICULA

Review of the scientific literature has shown that veterinarians need to be well-versed in the areas of animal welfare, animal behavior, and animal ethics. Not only are these topics identified by the OIE and the AAVMC as being essential components of veterinary training, veterinarians need to be able to communicate about these issues with their clients and the general public. If veterinarians are to become leaders in the field of animal welfare, then they must be properly versed in the complexities of the topic. Additionally, being aware of the issues related to animal use, as well as the resources available to help make difficult decisions (such as the AVMA Guidelines on Euthanasia), can help alleviate some of the stress associated with the veterinary profession.

In 2011, Broom said that "the decision by the American Veterinary Medical Association to promote the teaching of [animal welfare] in all American veterinary schools will have a substantial effect" (Broom, 2011). The survey conducted to explore the extent to which veterinary institutions have incorporated specific courses on these topics found that many American veterinary schools have not embraced the AVMA's decision, with only a fifth of schools offering a formal course on animal welfare. More institutions offered courses related to animal ethics and animal behavior (18 and 22, respectively). Formal courses are not the only way to incorporate these topics into the curriculum, though transparency about covered topics is important. Further research needs to evaluate the knowledge of veterinary students regarding these topics, as well as the students' perspective on how well veterinary schools are preparing them in animal welfare, behavior, and ethics.

The Animal Welfare Judging and Assessment Contest offers an extracurricular opportunity for students to learn about the intricacies of animal welfare. By spending a semester preparing for the competition, students learn about management practices for four different species, as well as general animal welfare principles. This teaches students better literature review skills, and applying the information in a competitive format improves knowledge retention. Oral presentation skills are enhanced via participation on the team, as are the skills required to objectively assess animal welfare. Further research on students' knowledge related to animal welfare is needed, comparing a group of students that participate on the team with a group of students that do not participate. While the AVMA provides some funding for travel of veterinary students, more financial investment by the university is needed to make this a sustainable program at CSU.

PREWEANED DAIRY CALF MANAGEMENT

The USDA NAHMS Dairy 2014 longitudinal heifer calf study was conducted to evaluate the management of dairy heifer calves from birth to weaning, and attempted to capture all events during that time period. Colostrum quality, passive transfer status, and average daily gain were the focus of these chapters. The final analysis of the calf component can be visualized in Figures 8.1 and 8.2.

One of the most important aspects of calf care is colostrum management, as passive transfer of immunity provides neonatal calves with critical resistance to infections early in life. Colostrum quality was evaluated, and overall colostrum quality was excellent, with a mean colostrum IgG of 74.4 g/L and more than three-quarters of the samples (77.4%) having colostrum IgG levels greater than 50 g/L. Colostrum IgG concentration was impacted by the source of the colostrum and the THI for the month prior to birth. Commercial colostrum

replacers had the lowest IgG concentrations, and colostrum from third or higher lactation dams had the highest IgG concentrations. Colostrum IgG was highest when the THI for the month prior to calving was greater than or equal to 70, and lowest when THI was less than 40. This means that colostrum replacers should be used as a last resort, and all colostrum should be tested for quality prior to feeding. Additionally, environmental factors during the dry period need to be mitigated as best as possible due to the influence on the colostrum quality.

Passive transfer of immunity was also evaluated, and again was found to be excellent, with a mean calf serum IgG concentration of 21.6 g/L and 73.3% of calves with serum IgG concentrations greater than 15 g/L. Passive transfer was impacted by the source of colostrum in a different pattern than seen for colostrum quality, with calves receiving colostrum from first lactation dams having the highest serum IgG, and calves receiving colostrum replacers having the lowest serum IgG. This further emphasizes that colostrum replacers should only be used if absolutely necessary, as the quality of these products does not mimic natural colostrum, and as a result, calves fed colostrum replacers do not receive enough IgG for adequate passive transfer of immunity. Calves fed heat-treated colostrum had higher serum IgG levels than calves not fed heat-treated colostrum, possibly due to decreased competition with microbes for absorption in the small intestine. Heat treatment provides an opportunity to improve passive transfer, particularly on operations that have a high prevalence of failure of passive transfer (FPT). Serum IgG increased as the timing to the first feeding decreased, total amount of colostrum fed in the first 24 hours increased, the age of the calf at blood sampling decreased, and the quality of the colostrum increased (colostrum IgG). These results reiterate what has been known for decades: it is important to feed calves an appropriate volume of high-quality colostrum as soon as possible after birth.

While overall passive transfer was excellent, 12.1% of calves still had FPT, giving them an increased risk of infections. Almost half of the calves with FPT (46.4%) received poor quality colostrum, indicating that more operations should incorporate testing of colostrum quality into their colostrum management programs. Overall, 14.2% of calves with FPT had no identified risk factors for FPT (low quality, low volume, delayed feeding). This identifies an area for further research to identify characteristics of calves that develop FPT with no observed risk factors.

Factors associated with average daily gain (ADG) in dairy heifer calves were evaluated during this study. Calves are considered to have excellent ADG for the preweaning period if their ADG>0.82 kg/day; only 33.3% of calves in the study met this goal. The mean ADG was 0.74 kg/day, and the preweaning period averaged 64.7 days. As expected, calves with no disease events during the preweaning period gained more weight than calves with one or more disease events. This finding underscores the importance of providing calves with proper colostrum for passive transfer of immunity as well as preventing disease. Also, calves fecal positive for *Cryptosporidium* or *Giardia* at the time of sampling had lower ADG than calves that were fecal negative for *Cryptosporidia* or *Giardia,* emphasizing the need for hygienic practices on-farm. Calves fed more protein in the liquid diet per day gained more, indicating that feeding high volumes and/or high quality liquid diets to calves improves overall calf growth. Calves that had a direct-fed microbial added to the liquid diet gained less than calves that did not have a direct-fed microbial, possibly detecting other issues on the operation. Calves fed milk gained more than calves fed milk replacer, perhaps because of the higher concentration of protein and fat in milk compared with most milk replacers. Calves gained better at lower THI levels, meaning better heat abatement techniques for calves should be investigated. This is consistent with

previous findings that show cooler temperatures stimulate starter intake. Keeping calves comfortable was also associated with improved ADG, and this study found that sand was not an appropriate bedding substrate for calves. While not in the final model, calves with lower birth weights tended to have lower ADG, as seen by the influence of twins and dam lactation on ADG, with calves from first lactation dams and twins having lower ADG. Overall, calves had improved ADG if they are kept healthy, provided an adequate volume and quality of a liquid diet, and environmental factors are mitigated.

A separate survey asked about the management of bull calves on the operations that participated in the heifer calf study. Often a forgotten entity on the dairy operation, very little information exists on bull calf management in the scientific realm. The colostrum management and dehorning practices were compared between bull calves and heifer calves. The results showed that bull calves were managed differently than heifer calves in those areas. Bull calves were fed colostrum later and a lower total amount in the first 24 hours compared with heifer calves. Further research to evaluated passive transfer status in bull calves is needed to determine if the current practices are providing bull calves with adequate passive transfer. Almost all operations sold bull calves prior to weaning, with calves leaving the operation at about one week old. The majority of operations did not dehorn or castrate bull calves prior to them leaving the operation. For those operations that do dehorn or castrate bull calves, pain management is usually not used, despite numerous research studies on the importance of and techniques for pain management. The surveyed operations that are using methods of dehorning and castration that have been shown to cause the most pain, including surgical techniques, are not using any pain relief for these procedures. These results identify a need for education for both dairy producers

and veterinarians on the current techniques available and the benefits of using analgesics and/or anesthetics for painful procedures in bull calves.

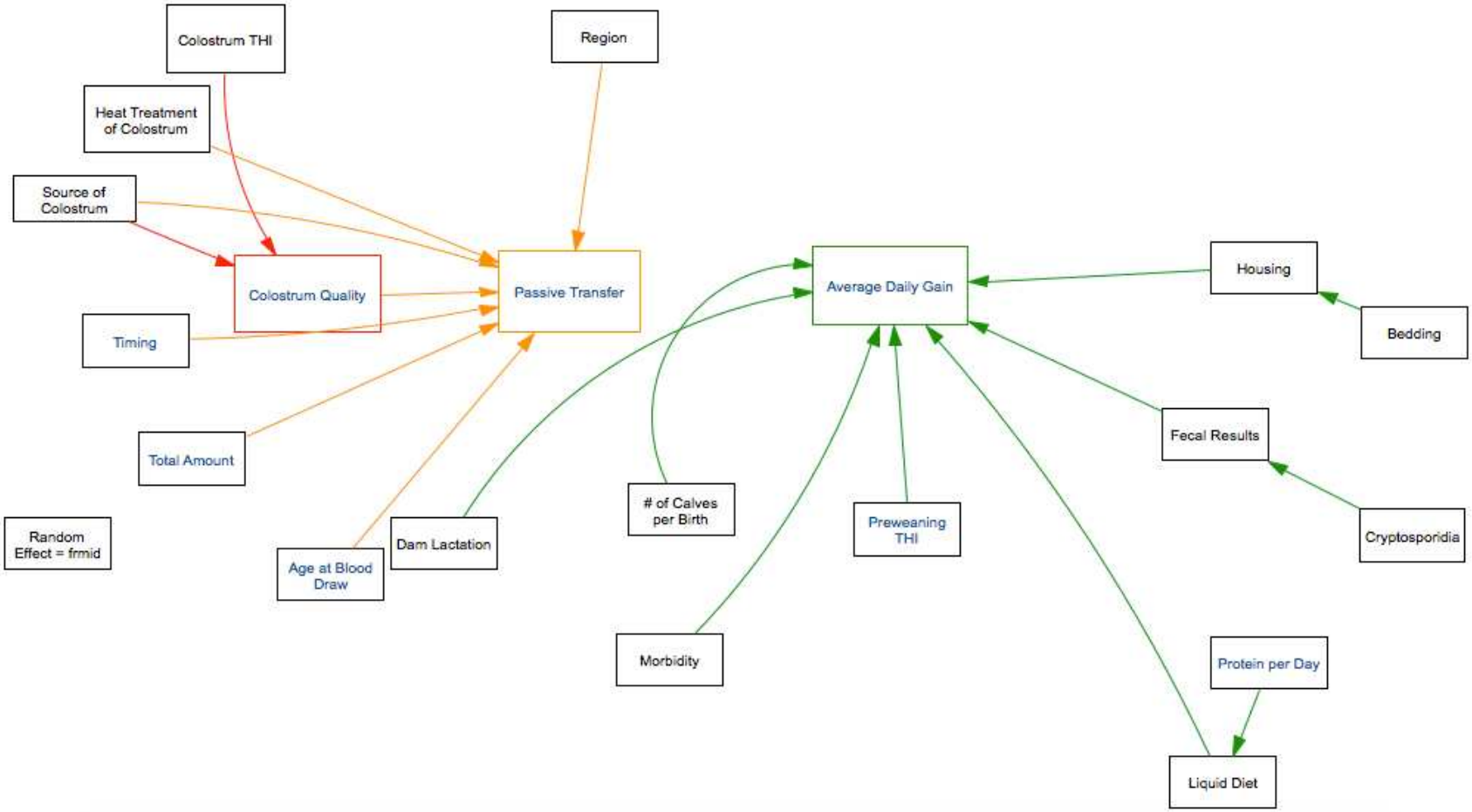

Figure 8.1. Final Heifer Calf Analysis. Continuous variables are shown in blue text, and categorical variables are shown in black text. This figure shows the variables that were significant for the multivariable models for colostrum quality (colostrum IgG), passive transfer (serum IgG), and average daily gain (kg/day).

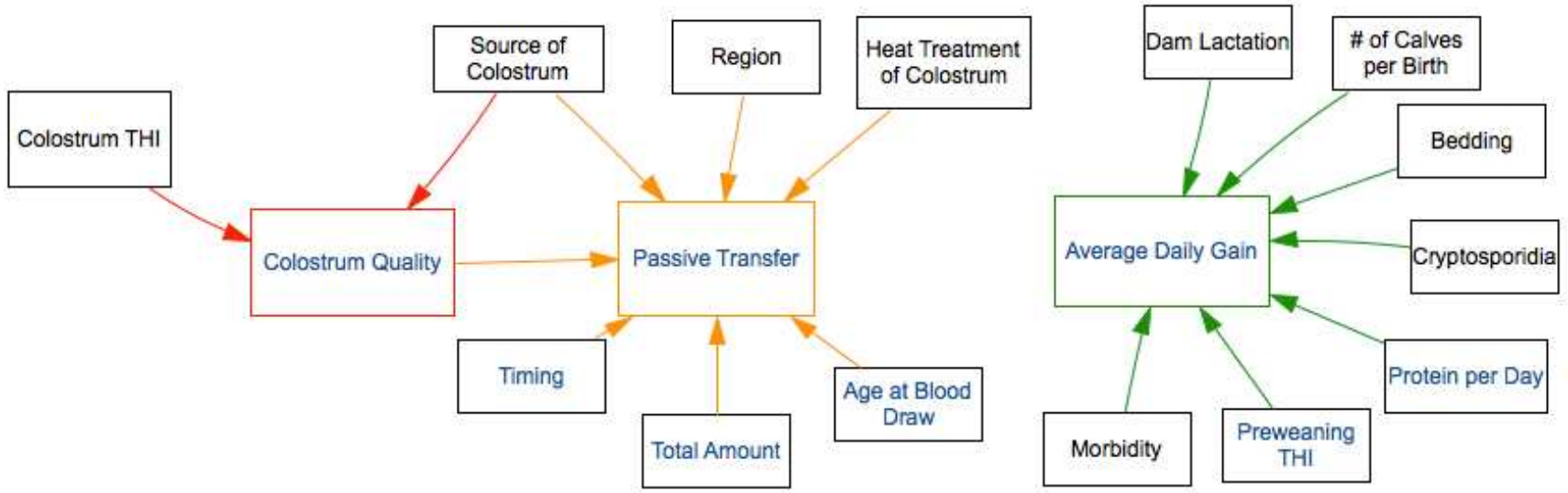

Figure 8.2. Final Heifer Calf Analysis (rearranged). Continuous variables are shown in blue text, and categorical variables are shown in black text. This figure shows the variables that were significant for the multivariable models for colostrum quality (colostrum IgG), passive transfer (serum IgG), and average daily gain (kg/day).

REFERENCES

Broom, D. M. 2011. A history of animal welfare science. Acta Biotheor. 59:121–37.

APPENDIX I:

Survey for Veterinary Curricula

Survey of Animal Welfare, Animal Behavior, and Animal Ethics: Courses and Content in Doctorate of Veterinary Medicine Programs

Animal Welfare
(Defined as how an animal is coping with the condition in which it lives.)

1. Do you offer a formal course(s) in animal welfare at your institution?
    a. Yes
        i. If yes, please indicate course number/name and contact person: _____
    b. No *(skip to question #7)*

2. Is the course required for all students in the program or offered as an elective?
    a. Required
    b. Elective
    c. Other (explain): _____

3. Please indicate the course format *(check one only)*:
    a. Lecture only
    b. Lab only
    c. Primarily lecture with some lab
    d. Primarily lab with some lecture
    e. Other (explain): _____

4. In what year(s) of the DVM curriculum is the course(s) offered *(check all that apply)*?
    a. Year 1
    b. Year 2
    c. Year 3
    d. Year 4

5. Please indicate which of the following topics are included in the course *(check all that apply)*:
    a. General animal welfare principles (e.g., five freedoms, euthanasia, pain)
    b. Companion animal welfare issues (e.g., spay/neuter, declawing, tail docking)
    c. Equine welfare issues (e.g., horse slaughter, soring, racehorse medications, cart horses)
    d. Livestock welfare issues (e.g., religious slaughter, feed supplements, housing conditions, branding, dehorning)
    e. Other animal welfare topics (please list) _____

6. Approximately how many full time equivalent (FTE) faculty/staff are devoted to animal welfare teaching at your institution?
    a. Less than 0.25 FTE
    b. 0.25-0.5 FTE
    c. >0.5-1.0 FTE
    d. >1.0-1.5 FTE
    e. >1.5-2.0 FTE
    f. >2.0-3.0 FTE

g. >3.0 FTE

Skip to question #9

7. If you DO NOT offer a formal course in animal welfare, do you plan to offer such a course (any format) as part of the DVM curriculum within the next five years?
    a. Yes
    b. No
    c. Do not know/unsure

8. If you DO NOT offer a formal course in animal welfare, please indicate any/all of the following topics that are incorporated into other formal required or elective courses. For those you select, please indicate course number/name and contact person.
    a. General animal welfare principles (e.g., five freedoms, euthanasia, pain)
        i. Course number/name and contact person: _____
    b. Companion animal welfare issues (e.g., spay/neuter, declawing, tail docking)
        i. Course number/name and contact person: _____
    c. Equine welfare issues (e.g., horse slaughter, soring, racehorse medications, cart horses)
        i. Course number/name and contact person: _____
    d. Livestock welfare issues (e.g., religious slaughter, feed supplements, housing conditions, branding, dehorning)
        i. Course number/name and contact person: _____
    e. Other animal welfare topics (please list): _____
        i. Course number/name and contact person: _____

9. Please indicate your agreement to the statement: The animal welfare training in our current curriculum adequately addresses the public demand for veterinarians to be knowledgeable of this subject *(check one only)*.
    a. Strongly agree
    b. Agree
    c. Neutral
    d. Disagree
    e. Strongly disagree

Animal Ethics

(Defined as the philosophical thinking about animal use, including different values and morals used to make decisions.)

10. Do you offer a formal course(s) in animal ethics at your institution?
    a. Yes
        i. If yes, please indicate course number/name and contact person: _____
    b. No

If YES, skip to question #13

11. If you DO NOT offer a formal course in animal ethics, do you specifically address ethics in other courses?
    a. Yes
        i. If yes, please list course number(s), name(s), and contact person(s):____
    b. No

12. If you DO NOT offer a formal course in animal ethics, does your institution sponsor experts to speak on campus?
    a. Yes
        i. How many times in the last 3 years?
        ii. Names of speakers in last 3 years: _____
    b. If yes, please indicate if the lecture(s) are optional or required.
        i. Required
        ii. Optional
        iii. Some required, some optional
    c. No

Animal Behavior
(Defined as the scientific study of how animals interact with each other, other living beings, and the environment.)

13. Do you offer a formal course(s) in animal behavior at your institution?
    a. Yes
        i. If yes, please indicate course number/name and contact person:_____
    b. Combined animal welfare/animal ethics course *(skip to question #14)*
    c. No *(skip to question #15)*

14. Is the course required for all students in the program or offered as an elective?
    a. Required
    b. Elective
    c. Other (explain): _____

15. Please indicate the course format *(check one only)*:
    a. Lecture only
    b. Lab only
    c. Primarily lecture with some lab
    d. Primarily lab with some lecture
    e. Other: _____

16. In what year(s) of the DVM curriculum is the course(s) offered *(check all that apply)*?
    a. Year 1
    b. Year 2
    c. Year 3
    d. Year 4

17. Please indicate which of the following topics are included in the course(s) *(check all that apply)*:
    a. Companion animal behavior
    b. Equine behavior
    c. Livestock behavior
    d. Other animal behavior topics (please list):
    _____

    Skip to question #16

18. If you DO NOT offer a formal course in animal behavior, please indicate any/all of the following topics that are incorporated into other formal required or elective courses. For those you select, please indicate course number/name and contact person.
    a. Companion animal behavior
        i. Course number/name and contact person: _____
    b. Equine behavior
        i. Course number/name and contact person: _____
    c. Livestock behavior
        i. Course number/name and contact person: _____
    d. Other animal behavior topics (please list)
        i. Course number/name and contact person: _____

General Questions

19. We welcome your comments about the inclusion of animal welfare, behavior, or ethics in the professional curriculum?
    _____

20. Any other comments? (If you have comments regarding individual questions, please identify them by question number.)
    _____

21. Please provide the following information
    a. Name: _____
    b. Institution:_____
    c. Position:_____
    d. E-mail address:_____

22. Can we contact you for follow-up questions (if any)?
    a. Yes
    b. No

23. Please provide a URL to your current curriculum.

APPENDIX II:

Heifer Calf Health Card

USDA

Animal and Plant Health Inspection Service

Veterinary Services

Heifer Calf Health Card
(Tarjeta lechera de becerras)

NAHMS Dairy 2014

National Animal Health Monitoring System

2150 Centre Ave, Bldg B
Fort Collins, CO 80526

Form Approved
OMB Number 0579-0205
Approval expires: 09/30/2016

NAHMS ID: _____ H101 **Dam ID:** _____ **(ID de la madre)** H101a	**<LABEL (LA ETIQUETA)>**	**Breed:** ☐1 Holstein ☐2 Jersey ☐3 Other (otra) H102 **(Raza)** **Dam lactation:** ☐ 1st ☐ 2nd ☐ 3rd or higher H102a **(lactancia de la madre)** (1era) (2da) (3era o más)

Birth Data (Datos de nacimiento)

Date of birth: __/__/__ (mm/dd/yy) H103
(fecha de nacimiento) (mes/día/año)

Birth weight: _____ cm _____ lb H104/H105 [Use supplied calf growth tape when calf is dry]
(Pesa al nacer) (libras) [Use la cinta de crecimiento provista cuando la becerra esta seca]

Calving ease:
(Grado de distocia/facilidad de parto) H106

- ☐1 Unassisted (no asistido)
- ☐2 Easy—1 person (fácil de extraer—una persona)
- ☐3 Difficult—2 or more people (difícil de extraer—2 o más personas)
- ☐4 Mechanical/surgical extraction (extracción mecánica o quirúrgica)

Number of calves born:
(Numero de nacidos)

- ☐1 Single (única)
- ☐2 Twins (mellizos)
- ☐3 Triplet (trillizos)

H107

Who attended the calving event?
¿Quién asistiendo el evento de parto?

- ☐1 Male (hombre)
- ☐2 Female (mujer)
- ☐3 Unattended (nadie asistido) H108

Was the navel disinfected?
(¿El ombligo desinfectado?)

- ☐1 Yes (sí)
  What product? _____
  ¿Qué producto?
- ☐3 No

H109/H109OTH

Colostrum Feeding Data (Datos de la alimentación de calostro)

Colostrum given? (¿Administró calostro?)	H110	☐1 Yes (sí) ☐3 No
Colostrum sample collected for quality testing? (¿Recolectó una muestra y evaluó la calidad de calostro?)	H111	☐1 Yes (sí) ☐3 No
Brix reading (if done on farm)? (¿Efectuó una lectura de Brix en la lechería?)	H112	_____%
Source of colostrum? (¿Fuente de calostro?)	H113	☐1 Dam of calf (madre de la Becerra) ☐2 Other dam (otra madre) ☐3 Pooled (múltiples madres)
Was colostrum pasteurized? (¿Pasteurizó el calostro?)	H114/H115	☐1 Yes (sí) If yes, what temperature? _____°F/C please circle F or C ☐3 No (¿En caso afirmativo, que temperatura?) (Marque con un circulo F o C)
How many hours after birth until colostrum was given? (¿Cuantos horas después del nacimiento administró el primer calostro?)	H116	_____ hours (horas)
Volume (in quarts) of first feeding: (Volumen, en cuartos, en la primera administración:)	H117	_____ qt (cts.)
Total colostrum given in first 24 hours (quarts): Volumen total (cts.) administrado en las primeras 24 horas):	H118	_____ qt (cts.)
Method of feeding the majority of colostrum? (¿Método de administración de calostro?)	H119	☐1 Bottle (botella) ☐2 Esophageal feeder (sonda intraesofagica)

Preweaning Data (Datos de Pre-Destete)

What is the gender of the person responsible for calf health? (¿Sexo de la persona responsable de monitorear los nacimientos?)	H120	☐1 Male (Hombre) ☐2 Female (Mujer)
Housing (Instalaciones)	H121/H122	☐1 Individual hutch/pen (jaulas individuales) ☐2 Group pen (corral grupal) Number in group pen _____ (numero en corral grupal)
Which of the following best describes ventilation of calf housing? (¿Cuál describe el mejor la ventilación de los instalaciones de los nacimientos?)	H123	☐1 Natural/outside ventilation Ventilación natural/afuera ☐2 Positive pressure tubes Tubos de presión positivo ☐3 Cross ventilation Ventilación mixta
Which of the following best describes the bedding used for the majority of the preweaning period? (¿Cuál describe el mejor la cama usada para la mayoridad del período destete?)	H124/H124OTH	☐1 Straw (la paja) ☐2 Shavings (las virutas) ☐3 Sand (la arena) ☐4 Manure biosolids (los bio-solidos del estiércol) ☐5 None (Nada) ☐6 Other (otro) _____
Dehorned? [If yes, write the date and describe drugs used.] (Descornado? [anote fecha y drogas usados en caso afirmativo])	H125/H126 H127/H127OTH	☐1 Yes (sí) __/__/__ ☐3No Medications for dehorning: (Drogas de descornado:) ☐1 Lidocaine _____

At what date was the calf first offered: (¿En qué fecha le ofreció a la Becerra:) H128/H129/H130/H131 Please attach a starter label. (Por favor adjunte la etiqueta de alimento indiciador.)	Water (Agua) __/__/__	Starter feed __/__/__ (Alimento iniciador) _____% protein (proteína)	Hay __/__/__ (Heno)

NAHMS–305
Jan 2014

ATTACH LABELS HERE
Adjuntó las etiquetas aquí

NAHMS Dairy 2014 Preweaned Heifer Calf Study Heifer calf ID: _____

Milk Feeding (Alimentación con Leche) MR = milk replacer (SL = sustituto lácteo)	
Milk replacer or whole (waste or saleable) milk? (¿Sustituto lácteo o leche entera?) H132	☐1 Replacer (sustituto) ☐2 Whole/waste milk (leche entera/ leche desperdicio) ☐3 Both (ambos)
If MR is fed, what is the formulation? How many ounces of powder is fed per feeding? Please attach milk replacer label. (Si administró SL, ¿qué es la formulación? ¿Cuantas onzas del polvo administró por alimentación? Por favor adjunte la etiqueta de SL.)	Formulation: _____% protein (proteína) / _____% fat (grasa) (Formulación:) Amount fed: _____ ounces (onzas) (cantidad administró) H133a/ H133b/ H133c
Acids/preservatives added to milk or MR? (¿Agregó ácidos o preservativos a la leche o SL?) H134/H134OTH	☐1 Yes (sí) ☐3 No Please specify: (por favor especifique)
Coccidiostats added to milk or MR? (¿Agregó coccidiostaticos a la leche o SL?) H135/H135OTH	☐1 Yes (sí) ☐3 No Please specify: (por favor especifique)
Any other additives added to milk or MR? (Agrego otros aditivos a la leche o SL?) H136/H136OTH	☐1 Yes (sí) ☐3 No Please specify: (por favor especifique)
Was milk pasteurized? (¿Pasteurizo la leche?) H137/H137OTH	☐1 Yes (sí) ☐3 No Please specify the time and temperature: (por favor especifique la cantidad de tiempo y la temperatura)
Are bacteria counts in the milk evaluated? (¿Evaluó los números de bacterias en la leche?) H138/H138OTH	☐1 Yes (sí) ☐3 No Please specify last level: (por favor especifique la nivel final:)
Which of the following milk delivery systems were used for this calf? (Check all that apply.) ¿Cuáles de las sistemas de administración de leche uso para esta becerra? (marque todos que aplique) H139	☐1 Bottle (botella) ☐2 Bucket/pail (la cubeta) ☐3 Milk bar (barra de leche) ☐4 Robotic (el robótico)

Milk Consumption Record (Registro de Consumo de Leche)

Calf age in weeks **(Edad de Becerra en semanas)** (Example: Week 1- Week 3) (Ejemplo: Semana 1- Semana 3)	**Amount of milk offered [qts.]** **(Cantidad de leche ofrecida [cts.])** (__2__ qt (cts.))	**Frequency per day** **(Frecuencia cada día)** (__2__ times per day (veces por día))
H140	_____ qt (cts.) H141	_____ times per day (veces por día) H142
H143	_____ qt (cts.) H144	_____ times per day (veces por día) H145
H146	_____ qt (cts.) H147	_____ times per day (veces por día) H148
H149	_____ qt (cts.) H150	_____ times per day (veces por día) H151
H152	_____ qt (cts.) H153	_____ times per day (veces por día) H154

Preweaning Growth Record (Registro de Crecimiento Previo al Destete)
Use supplied Calf Growth Tape (Use la cinta de crecimiento provista)

Calf age (Edad de Becerra)	**Date (Fecha)**	**Weight (Pesa)**		**Hip Height (Altura)** (cm)
		Cm	**Lb** (libras)	
~2 weeks of age (~2 semanas de edad)	__/__/__ H155	H160	H165	H170
~4 weeks of age (~4 semanas de edad)	__/__/__ H156	H161	H166	H171
~6 weeks of age (~6 semanas de edad)	__/__/__ H157	H162	H167	H172
~8 weeks of age (~8 semanas de edad)	__/__/__ H158	H163	H168	H173
At weaning	__/__/__ H159	H164	H169	H174

Biologic Sampling Record (Registro de Muestras Biológicas)

1 to 5 days after birth (1 a 5 días después de nacimiento)	**Date (Fecha)**	
Blood drawn for total protein (Extracción de sangre para evaluación de proteínas totales)	__/__/__ H175	
Ear notch for BVD testing (Muesca de oreja para prueba de BVD) H176/H177	__/__/__	BVD result (Resultos de BVD) ☐1 Negative (Negativo) ☐3 Positive (Positivo)
2 to 4 weeks after birth (2 a 4 semanas después de nacimiento)	**Date (Fecha)**	
Was a fresh fecal simple collected? ☐1 Yes (sí) ☐3 No (¿Colegió una muestra de material fecal fresca?) H179	__/__/__ H180	

Vaccinations (Vacunaciones) Brand name (Marca comercial)	**Date of administration (Fecha de administración)**
H181	__/__/__ H182
H183	__/__/__ H184
H185	__/__/__ H186
H187	__/__/__ H188
H189	__/__/__ H190

2

Disease Incidence and Treatment (Incidencia de Enfermedades y Tratamientos)

Enter date of illness and/or treatment. (Pone la fecha de enfermedades y/o tratamiento.)
Check all boxes that apply for this occurrence [one column per disease event].
(Marque todas las casillas que aplican para este evento [una columna por evento de enfermedad].)

Date illness started (Fecha Inicial de la enfermedad)	__/__/__ H191	__/__/__ H212	__/__/__ H233	__/__/__ H254	__/__/__ H275	__/__/__ H296
Final treatment date (Fecha Final del tratamiento)	__/__/__ H192	__/__/__ H213	__/__/__ H234	__/__/__ H255	__/__/__ H276	__/__/__ H297
Initial Signs (Signos Clínicos):						
Initial temperature (°F) (Temperatura) (Write in NA if not taken.) (anote NA si no se ha registrado)	H193	H214	H235	H256	H277	H298
Listless, droopy ears, dull, off feed (Apatía, orejas caídas, deprimida , no se alimenta)	☐ H194	☐ H215	☐ H236	☐ H257	☐ H278	☐ H299
Dehydrated, sunken eyes (Deshidratación, ojos hundidos)	☐ H195	☐ H216	☐ H237	☐ H258	☐ H279	☐ H300
Scours, diarrhea (Diarrea)	☐ H196	☐ H217	☐ H238	☐ H259	☐ H280	☐ H301
Cough, runny nose or eyes, difficulty breathing (Tos, secreciones nasals u oculares, dificultad respiratoria)	☐ H197	☐ H218	☐ H239	☐ H260	☐ H281	☐ H302
Lameness, joint problems (Renguera, problemas articulares)	☐ H198	☐ H219	☐ H240	☐ H261	☐ H282	☐ H303
Head tilt (inclinación de la cabeza)	☐ H199	☐ H220	☐ H241	☐ H262	☐ H283	☐ H304
Other, specify (Otros, especifique):	H200	H221	H242	H263	H284	H305
Treatments (Tratamientos):						
Cut back on amount of milk or replacer fed (Reducción de cantidad o cambio de leche o sustituto lácteo)	☐ H201	☐ H222	☐ H243	☐ H264	☐ H285	☐ H306
Changed milk or replacer (Reducción de cantidad o cambio de leche o sustituto lácteo)	☐ H202	☐ H223	☐ H244	☐ H265	☐ H286	☐ H307
Oral electrolytes (Electrolitos orales)	☐ H203	☐ H224	☐ H245	☐ H266	☐ H287	☐ H308
Injectable fluids (Fluidos inyectables)	☐ H204	☐ H225	☐ H246	☐ H267	☐ H288	☐ H309
Drugs administered (Drogas administradas)	☐ H205	☐ H226	☐ H247	☐ H268	☐ H289	☐ H310
Code (from last page) for drugs (include antibiotics, anti-inflammatories, probiotics: [Código (de la página ultima) de las drogas (incluya antibióticos y anti-inflamatorios):]	____, ____, ____, ____ H206/H207/ H208/H209	____, ____, ____, ____ H227/H228/ H229/H230	____, ____, ____, ____ H248/H249/ H250/H251	____, ____, ____, ____ H269/H270/ H271/H272	____, ____, ____, ____ H290/H291/ H292/H293	____, ____, ____, ____ H311/H312/ H313/H314
Fed gut soothers (e.g., Pepto-Bismol®/ Kaopectate®) [¿Administro protectores del intestino (e.g., Pepto-Bismol®/Kaopectate®)?]	☐ H210	☐ H231	☐ H252	☐ H273	☐ H294	☐ H315
Other, specify (Otros, especifique):	H211	H232	H253	H274	H295	H316

☐1 This calf did not have illness during the preweaning period (Esta becerra no estuvo enferma en el periodo previo al destete) H317

Did the calf die? (¿Murió la becerra?) ☐1 Yes (sí) ☐3 No Date: __/__/__ (Fecha) Reason: (Razón) H318a/H318b/H318OTH

Weaning Data (Datos de Destete)

Date weaned: (Fecha de destete:)	__/__/__	H319
Criteria to wean calf (Criterio para destetar a la becerra)	☐1 Starter intake (Consumo de comida) ☐2 Age (Edad) ☐3 Lack of space (Falta de espacio) ☐4 Other, specify: (Otro, especifique)	H320/H320OTH
Were preventive treatments given at weaning? (¿Administro tratamientos preventivos at destete?)	☐1 Yes (sí) Please describe: (Por favor describe:) ☐3 No	H321/H321OTH

Code (Codigo)	Product name (Nombre del producto)
1	Adspec®
2	Agrimycin™ 200
3	Amoxi-Bol®
4	Bactrim® tablets
5	Banamine
6	Baytril® 100 injectable
7	Biosol® liquid
8	Bio-Mycin® 200
9	BO-SE
10	Calf Pro®
11	CORID 9.6% oral solution
12	Draxxin™
13	Durapen™
14	Excede™ sterile suspension
15	Excenel® RTU
16	Flumeglumine®
17	Flunixin injection
18	Flunazine
19	Liquamycin® LA-200
20	Micotil® 300 injectable
21	Naxcel®
22	Neomycin oral solution
23	Nuflor® injectable solution
24	Pen-G Max™
25	Penicillin G Procaine
26	Polyflex®
27	Pro-Pen-G™ injectable
28	Recovr injectable
29	Resflor Gold®
30	Re-sorb®
31	SMZ-TMP tabs
32	Sustain III® cattle bolus
33	Tetradure 300
34	Tribrissin® tablets
35	Uniprim powder
36	Vital E
Other medications used (Nombre de otros medicamentos utilizados)	
50	
51	
52	
53	
54	
55	

Additional Notes? ☐1 Yes (sí) ☐3 No H322
(¿Información adicional?)

If you have any additional notes or information about this calf, please add it here.
(Si tiene información adicional u información sobre esta becerra, por favor la ponga aquí.)

APPENDIX III:

Bull Calf Questionnaire

USDA

Animal and Plant Health Inspection Service

Veterinary Services

Dairy 2014
Bull Calf Questionnaire

National Animal Health Monitoring System

2150 Centre Ave Bldg B
Fort Collins, CO 80526

Form Approved
OMB Number 0579-0205
Approval expires:
09/30/2016

State FIPS:	Operation #:	Interviewer:	Date:
2 digits	4 digits	Initials	mm/dd/yy

1. Of the dairy bull calves born on this operation during 2014, how many were:
   a. Born and still alive at 48 hours? ..... _____ #
   b. Stillborn (born dead or died within 48 hours of birth)? ..... +_____ #
   c. Total bull calves born (alive and dead)? ..... =_____ #

2. During 2014, what percentage of newborn dairy bull calves received colostrum? ..... _____ %

[If question 2 = 0, SKIP to question 6.]

3. During 2014, what percentage of newborn dairy bull calves received colostrum by:
   a. Hand feeding only (no suckling the cow)? ..... _____ %
   b. Both hand feeding and suckling the cow? ..... +_____ %
   c. Suckling the cow only (not hand fed)? ..... +_____ %
   Total ..... = 100%

[If question 3c= 100, SKIP to question 6.]

4. During 2014, how many hours following birth did the majority of newborn dairy bull calves get their first feeding of colostrum? ..... _____ hr

5. How many quarts of first-milking colostrum were normally hand fed to dairy bull calves:
   a. At the first feeding? *[If allowed to nurse prior to hand feeding, enter 0.]* ..... _____ qt
   b. In all subsequent feedings in the first 24 hours? ..... +_____ qt
   c. Total in the first 24 hours? ..... =_____ qt

NAHMS-315
JAN 2014

6. During 2014, were bull calves routinely sold prior to weaning? ..... ☐1 Yes ☐3 No

   If Yes, at what age (in days or weeks) did the majority of dairy bull calves leave the operation? ..... _____ days **OR** _____ weeks

7. During 2014, were any bull calves dehorned while on this operation? ..... ☐1 Yes ☐3 No

[If question 7 = No, SKIP to question 9.]

8. During 2014, what percentage of bull calves were dehorned by the following methods? What was the average age of calves (in weeks)? Were analgesics or anesthetics used?

	% Bull calves	**Age** (weeks)	**Analgesics/ anesthetics**
a. Hot iron (Buddex, electric, Portasol)	_____	_____	☐1 Yes ☐3 No
b. Caustic paste	_____	_____	☐1 Yes ☐3 No
c. Tube, spoon, or gouge	_____	_____	☐1 Yes ☐3 No
d. Saws, wire, or Barnes	_____	_____	☐1 Yes ☐3 No
e. Other (specify: _____)	_____	_____	☐1 Yes ☐3 No
Total *[should be ≤100%]*	_____		

9. During 2014, what percentage of dairy bull calves were born alive but died prior to weaning or leaving the operation? ..... _____ %