THESIS

PRELIMINARY EXPLORATION OF THE EFFECTS OF EXTENDED COLOSTRUM FEEDING ON CALF LYING BEHAVIOR AND FACTORS ASSOCIATED WITH STUDENT SUCCESS IN AN INTRODUCTORY LEVEL ANIMAL SCIENCE COURSE

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ABSTRACT

PRELIMINARY EXPLORATION OF THE EFFECTS OF EXTENDED COLOSTRUM FEEDING ON CALF LYING BEHAVIOR AND FACTORS ASSOCIATED WITH STUDENT SUCCESS IN AN INTRODUCTORY LEVEL ANIMAL SCIENCE COURSE

This thesis consists of two projects: assessing the effects of supplementing colostrum in the diet of preweaned non-replacement dairy calves beyond the first 24 hours of age on lying behavior (Project 1) and assessing factors associated with student final grades in an introductory animal science course (Project 2).

The objective of Project 1 was to determine if extended colostrum feeding (ECF) from 0-14 d was associated with preweaned dairy calf behavior. Feeding colostrum beyond 24 h of age has been seen to improve calf health and growth, yet the behavioral impacts are unknown. Neonatal Holstein and Holstein-Limousin calves (n = 26) were enrolled after they received 4L of maternal colostrum at birth and 4L 8 hours later, according to the dairy's existing protocol. Calves were transported 40km to a university teaching and research facility at 1 d of age. Calves were randomly assigned to treatment (COL; fed milk replacer + 44g colostrum replacer for the first 14 days, average Brix value = 14.5%) or control (CON; fed only milk replacer, average Brix value = 12.2%) upon arrival and blocked by breed and sex (n = 15 females, n = 11 males). Electronic loggers were attached to the hind leg of each calf for 4 d to record lying time, number of lying bouts, and lying bout duration during weeks 1, 2, 3, and 8 of life. Calves were weighed and average daily gain (ADG) was calculated at the end of each week. Health and fecal scores were assigned to each calf using a 0-3 scale twice weekly; clinical respiratory disease was defined as a sum of scores ≥ 5 or

two or more scores ≥ 2 and diarrhea was defined as a fecal score ≥ 2. Thoracic ultrasounds were performed weekly, and scores were assigned to each calf using a 0-3 scale; pneumonia was defined as a score ≥ 2. Lying behavior and diarrhea were analyzed using multivariable logistic regressions; ADG and feed-to-gain ratios were analyzed using multivariable linear regression. All models controlled for breed and sex with week as a repeated measure. Other health measures were reported via summary statistics. Treatment was not associated with proportion of time spent lying (CON: 78.8 ± 1.5%; COL: 79.5 ± 2.5%; $P = 0.0.63$), number of daily lying bouts (CON: 23.8 ± 1.1; COL: 23.7 ± 1.1; $P = 0.96$), or average lying bout duration (CON: 48.5 ± 3.3 min; COL: 49.6 ± 3.3 min; $P = 0.71$). Treatment was not associated with ADG within the first two weeks of life ($P = 0.39$) or throughout the preweaned period ($P = 0.88$), nor was it associated with feed-to-gain ratios for milk ($P = 0.24$) or for grain ($P = 0.74$). Ninety-two percent (12/13) of COL calves and 100% of CON calves had diarrhea at least once during the study period ($P = 0.18$). Eight percent (1/13) of COL calves and 15% (2/13) of CON had clinical and/or subclinical respiratory disease at least once during the study period ($P = 0.0.34$). Treatment was not associated with incidence of scours ($P = 0.18$) or incidence of respiratory disease ($P = 0.57$). This pilot study did not find associations between ECF and lying behavior, growth, or health during the preweaned dairy calves. However, this information can be used to refine sample sizes and measurements in future studies.

The objective of Project 2 was to determine if demographic factors and academic behaviors such as involvement in extracurricular activities, study strategies, notetaking habits, and attendance patterns were associated with students' final grade in a 100-level Introductory Food Animal Science course at Colorado State University (CSU). The impact of demographic factors and student academic behaviors or habits on student success are well-documented in many science disciplines, yet little data exists for animal science programs. Students enrolled in the course at

CSU during the fall 2021, 2022, and 2023 semesters (n = 556) were asked to complete an anonymous survey at semester's end regarding their final grade, academic behaviors, and demographics. Survey question types included multiple choice, Likert-scale, and short answer. Multivariable logistic regressions assessed associations between final course grade (pass: 'A', 'B', or 'C'; fail: 'D', or 'F'; outcome) and involvement in departmental extracurriculars (yes/no), perceived adequacy of study skills and notetaking strategies (Likert), attendance patterns (Attended 100%/Attended 80-90%/Attended < 70%), self-reported high school GPA (HSGPA; ≥ 4.00, 3.00-3.99, < 3.00), race (white/racially minoritized), number of times enrolled in the course (1/ >1), and first-generation (FG) status (yes/no). Students that had meaningful connections with faculty and those that were involved in clubs, research, and/or voluntary animal feeding were associated with a lower predicted probability of earning a failing grade compared to those who were not involved ($P = 0.0060$, $P = 0.0027$, $P = 0.0125$, $P = 0.0013$, respectively). Students with perceived inadequacies in study skills and notetaking strategies were associated with a lower predicted probability of passing compared to those who felt their skills were adequate ($P = 0.0018$ and $P < 0.0001$, respectively), yet no differences of probability of earning a failing grade were seen between students with different notetaking strategies ($P = 0.6616$) or quantities of time spent studying for quizzes or exams ($P = 0.4353$ and $P = 0.3703$, respectively). Students who attended class 80-90% of the time or less than 70% of the time were associated with lower odds of passing, compared to those who attended 100% of class periods ($P = 0.0099$ and $P = 0.0045$, respectively), but no differences were seen between those attending 100% of the time and those attending 90-100% of the time ($P = 0.1854$), nor was there a difference seen between those attending 80-90% and those attending less than 70% of the time ($P = 0.2032$). An interaction occurred between FG and HSGPA ($P = 0.0397$), which showed lower probabilities of earning a failing grade for non-FG

students compared to FG students at each of the three levels of HSGPA (≥ 4.00: $P = 0.0158$; 3.00-3.99: $P = 0.0184$; < 3.00: $P = 0.0341$). Racially minoritized students and students retaking the course had a higher probability of earning a failing grade in the course than their respective counterparts ($P < 0.0001$ and $P = 0.0030$, respectively). This study highlights the roles of involvement, attendance, perceived inadequacies in learning behaviors, and various demographics in academic performance and can be used to inform future student support programs in animal science disciplines.

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1. REVIEW OF LITERATURE

1.1 Introduction

Animal welfare was defined by the Brambell Committee (1966) as the state of an animal that encompasses both the animal's physical and mental well-being. As defined by Fraser et al. (2009), good animal welfare promotes positive biological functioning, affective states, and natural living for all animals (Fraser, 2009). Animal welfare is a critical research topic in livestock production because poor welfare in animals, such as stress, disease, or inadequate nutrition, can negatively impact growth, health, comfort, and long-term productivity (Buczinski et al., 2021; Machado and Ballou, 2022). Improving welfare of livestock not only enhances animal well-being but also supports sustainable and economically efficient production systems (von Keyserlingk et al., 2009).

One group of production animals that has seen increased research efforts in recent years, especially in terms of improving welfare, are non-replacement dairy calves (Bolton and von Keyserlingk, 2021; Creutzinger et al., 2021). Non-replacement calves are mostly male dairy calves and, more recently, dairy-beef crossbred calves designed to enter the beef supply, which have historically been seen as a by-product of the dairy industry and thus have not held much value (Creutzinger et al., 2021; Webb et al., 2023). Although current prices are high, non-replacement calves' historically low value has led to a distinct difference in the quality of neonatal care for these animals compared to those being retained on farm for dairy production. This includes poor colostrum delivery and management and lack of key preventative health measures such as navel dipping and vaccines, all of which can stunt development of the calves' immune systems and therefore increase the risk of morbidity and mortality (Renaud et al., 2017; Renaud et al., 2018b; Shivley et al., 2019). Further, many calves born on a dairy are subjected to early-life stress from transport events that can occur as early as 24h after birth (Pempek and Cramer, 2023), however non-replacement calves are especially susceptible to the negative effects of stress due to the poor colostrum management and preventative health measures in the neonatal period leading to underdeveloped immune systems (Vicic et al., 2022; Bajus et al., 2024). Recent reports have shown that non-replacement calves arriving at calf-raising facilities are in poor condition with inflamed navels, respiratory distress, dehydration, and hunger (Pempek et al., 2017; Bajus et al., 2023; Goetz et al., 2023). Further, non-replacement calves experience high morbidity rates during the preweaned period, with 66.9% of non-replacements exhibiting signs of diarrhea and 58.3% exhibiting signs of respiratory illness, whereas only 17% and 9.5% of replacements have been reported exhibiting the same (USDA NAHMS, 2022; Pereira et al., 2024). Improving morbidity and mortality among non-replacement calves helps provide better welfare for these animals, minimize economic losses to therapeutic treatments, and improve productivity and profitability of the beef supply chain.

One key area of care that can improve morbidity and mortality of preweaned calves is nutrition (Conneely et al., 2014; Habing et al., 2017; Cangiano et al., 2020). One nutritional intervention that has been proposed in recent years is extending the feeding of colostrum beyond 24 hours of life to help the calves' immune systems to continue to develop after initial colostrum feedings (Chamorro et al., 2017; McCarthy et al., 2024; Wang et al., 2025). The bioactive immune compounds found in increased concentrations in colostrum compared to regular milk could help create a localized immunity in the small intestine, minimizing absorption of pathogens into systemic circulation (Prenner et al., 2007; Ewaschuk et al., 2008). Recent research suggests that supplementing colostrum in the diet beyond the first day of life may enhance immune development and reduce diarrhea, respiratory illness, and treatment days in calves compared to those fed only milk replacer (Berge et al., 2009; Chamorro et al., 2017; Kargar et al., 2020a; Wang et al., 2025). However, there have been no studies looking specifically at the impacts of extending colostrum feeding beyond 24 hours of life on calf lying behavior, a metric that has been identified as a key indicator of an animal's overall comfort as well as a tool for early disease detection (Bonk et al., 2013; Zhang et al., 2024). Given that both health and nutrition have been shown to impact calf behavior, it is reasonable to suspect that extended colostrum feeding would impact calf lying behavior (Habing et al., 2017; Urie et al., 2018; Cangiano et al., 2020; Goharshahi et al., 2021; Zhao et al., 2022). Thus, the objective of this narrative literature review is to summarize current knowledge on the benefits of extended colostrum feeding protocols and the impact they may have on non-replacement calf welfare, including expression of lying behavior and health.

1.2 Non-Replacement Dairy Calf Management Challenges

In the United States alone, there are over 9.3 million dairy calves born each year (National Agricultural Statistics Service, Agricultural Statistics Board, United States Department and of Agriculture, 2025). Of these, approximately half are considered unsuitable or undesirable for use as replacements for cows currently in the milking herd and are commonly referred to as "surplus" or "non-replacement" calves (Bolton and von Keyserlingk, 2021; Creutzinger et al., 2021a; Bajus et al., 2023; Cramer et al., 2024). Non-replacement calves are primarily male but can also include females not fit for future breeding and beef-on-dairy cross calves (calves born to dairy-type dams and beef-type sires) (Creutzinger et al., 2021). Traditionally, these calves are sold by the source dairy within one to seven days of life and marketed through a third-party before entering one of three beef supply chains: "bob" veal to be harvested at < 3 weeks of age, "special-fed" veal to be harvested at 20-22 weeks of age, or dairy-beef to be harvested at 12-14 months of age (Pempek and Cramer, 2023; Maggard et al., 2024). Since non-replacement calves do not go on to replenish the milking herd and are often sold at significantly lower rates than replacement animals, they have historically had little to no economic value for most producers and were viewed only as a by-product of the dairy industry (Webb et al., 2023). However, this is quickly changing with the rise of beef-on-dairy cross calves, where the price of non-replacement calves was around $30-$60/cwt in 2019 but has increased to over $1100/cwt in some markets in 2025, causing more calves than ever to leave the dairy and enter the beef supply chain (USDA Agricultural Marketing Service, 2019; USDA Agricultural Marketing Service, 2025). As the value and industry prevalence of non-replacement calves continues to rise, a push for improved neonatal care, reduced disease incidence and treatment duration, and increased productivity in non-replacement animals continues to show up throughout the industry, leading to a heavier research focus on these animals. A key focus of this effort includes research conducted around colostrum management at the source dairy; From this, it was reported that non-replacement calves are receiving less adequate colostrum than replacements, contributing to health and growth challenges later in life (Creutzinger et al., 2021). This includes a delayed first feeding of colostrum (Shivley et al., 2019), reduced total volume of colostrum being fed (Renaud et al., 2017; Hendricks et al., 2022), and increased bacterial contamination of colostrum being fed (Fecteau et al., 2002), all of which have been linked to poorly developed or weakened immune systems, making the animals more susceptible to disease (Windeyer et al., 2014a; Pempeck and Cramer, 2023). Ingestion of adequate quality maternal colostrum quickly after birth is essential for the development of the neonate's immune system (Godden et al., 2019), so by experiencing subpar colostrum management on the source dairies, non-replacements are set at an immunological disadvantage at an early age (Windeyer et al., 2014a;

Urie et al., 2018). Non-replacement calves have also been reported to have decreased incidence of navel dipping (Renaud et al., 2017) and reduced veterinary care and oversight compared to replacement calves (Renaud et al., 2018a), which can exacerbate this issue further. Having an underdeveloped immune system and poor early-life veterinary care can lead to increased morbidity and mortality later in life, as well as decreased productivity, making this an issue not only of animal welfare but also of overall farm economics (Murray et al., 2016; Buczinski et al., 2021; Machado and Ballou, 2022).

In addition to poor neonatal care, shortly after receiving colostrum on the source dairy, non-replacement calves are sold into the beef and/or veal industries, typically at less than one week of age with some even younger than 24 hours of age (Creutzinger et al., 2021; Goetz et al., 2023; Pempek and Cramer, 2023). Once sold, they are transported up to 1300 km from their source dairy to calf-raising facilities in the beef-supply chain, often with multiple stops at auction markets or transfer stations (Creutzinger et al., 2021; Bajus et al., 2023). During transport, these calves face numerous stressors including long periods without access to feed and water, handling and loading stress, inadequate space allowance on the trailer, inclement weather, and commingling stress with calves from numerous source dairy farms (Wilson et al., 2020; Bajus et al., 2023). These stressors during transport, coupled with poor colostrum feedings, are likely why the non-replacement calves commonly arrive at calf-raising facilities in poor conditions (Vicic et al., 2022; Bajus et al., 2024). Past surveys of calves arriving to veal operations or calf-raising facilities report that a large proportion of calves arrive exhibiting signs of hunger (Creutzinger et al., 2021; Bajus et al., 2023), dehydration (Pempek et al., 2017), fatigue (Bajus et al., 2023), respiratory disease (Pardon et al., 2012; Scott et al., 2019; Goetz et al., 2023), navel inflammation (Pempek et al., 2017; Marquou et al., 2019; Pempek and Cramer, 2023), and diarrhea (Pempek et al., 2017; Scott et al., 2019; Goetz et al., 2023). This is troublesome for many reasons, the most concerning being that past studies have shown that young calves arriving at calf-raising facilities with any of the previously mentioned conditions are at higher risk for morbidity and mortality during the first few weeks of life (Renaud et al., 2018b; Creutzinger et al., 2021; Goetz et al., 2023). When non-replacement calves begin their lives with an underdeveloped immune system due to poor colostrum feeding and are then immediately subjected to a high pathogen load and increase in physical and emotional stressors, it is no surprise that they are arriving at calf-raising facilities in poor condition (Goetz et al., 2022).

One study by Wilson et al. (2000) does report that health conditions such as dehydration, body condition score, and rates of respiratory issues decrease in non-replacement calves over time at calf ranches, however the morbidity and mortality rates are still high for these animals even after this decrease (Wilson et al., 2000). Mortality in non-replacement calves on calf ranches and veal plants typically ranges from 3-8% across facilities in Canada and Europe (Bähler et al., 2012; Pardon et al., 2012; Winder et al., 2016; Renaud et al., 2018b; Goetz et al., 2021), with over 40% of deaths occurring within the first three weeks after arrival (Renaud et al., 2018b; Scott et al., 2019). Morbidity in non-replacement calves is also extremely high, with 68–90% of calves treated at least once for disease, most commonly diarrhea or respiratory illness (Scott et al., 2019; Creutzinger et al., 2021; Goetz et al., 2021). In one study of non-replacement calves conducted on a California calf ranch, 66.9% of the calves showed signs of diarrhea and 58.3% showed signs of respiratory disease in the first 60 days following arrival (Pereira et al., 2024). By contrast, a national survey conducted in 2014 by the USDA National Animal Health Monitoring System looking at replacement heifer health reported a 5% average mortality rate and 33.8% overall morbidity rate, with 17% and 9.5% of replacement heifers showing signs of digestive illness and respiratory illness, respectively (USDA NAHMS, 2022). While mortality rates may not be that different between replacement and non-replacement calves, there does seem to be a major discrepancy in morbidity rates, which could be due to poor neonatal care, transport stress, commingling stress from contact with unfamiliar animals on the calf ranch, or low planes of nutrition offered to non-replacement calves on calf ranches (Creutzinger et al., 2021; Pempeck and Cramer, 2023; Bajus et al., 2024).

1.3 Colostrum

All calves are born hypogammaglobulinemic (Weaver et al., 2000), meaning they lack key immunoglobulins needed to build an effective immune system. This is due to the separation of the maternal and fetal blood supplies by the syndesmochorial placenta of the cow, which prevents transmission of immunoglobulins from dam to calf in utero (Arthur et al., 1996). The naïve immune system of the newborn calf therefore needs to be developed and strengthened after birth, which is primarily accomplished through the intake of maternal colostrum (Cardoso et al., 2021). Colostrum is defined as the secretion from the mammary glands that is produced directly prior to giving birth and through the first one to two days following parturition, often provided for calves during the first few feedings following birth (Foley and Otterby, 1978; Puppel et al., 2019). Colostrum is only available for the neonate within the first one to two feedings, as the dam will begin to produce transition milk starting as early as the second feeding and eventually will switch to producing only regular milk around the sixth feeding (Blum and Hammon, 2000; Godden, 2008). The importance of colostrum compared to both transition milk and regular milk is due to its composition being vastly different (McGrath et al., 2016) such that colostrum is higher in concentration of total solids, fat, and protein, but lower in concentration of lactose (McGrath et al., 2016; Puppel et al., 2019; Fischer-Tlustos et al., 2020). For example, the first milking of colostrum contains approximately 16.8% protein, 6.7% fat, 2.9% lactose, and 24% total solids, whereas mature milk has 3.2% protein, 3.8% fat, 4.6% lactose, and 12.9% total solids (Foley and Otterby, 1978; Puppel et al., 2019). Transition milk allows for a stepdown process for these nutrients so that it is not so stark a contrast from colostrum to regular milk; Thus, the composition of transition milk often falls in between that of colostrum and mature milk. The higher concentration of fat in colostrum is beneficial in thermoregulation and in supplying energy to the neonate and the higher concentration of protein is beneficial to the calf's own protein synthesis and absorption of immunoglobulins (Quigley and Drewry, 1998). Additionally, past research has proven that feeding higher total solids percentages to calves increases their overall gain and reduces stress in the pre-weaned period (Rufino et al., 2019; Azevedo et al., 2023).

Along with an increased concentration of macronutrients, maternal colostrum is known for its higher concentration of bioactive compounds compared to mature milk, including oligosaccharides, lactoferrin, insulin and insulin-like growth factors, maternal leukocytes, and immunoglobulins (Ig), all of which aid in development of the neonate's immune system. Oligosaccharides, a saccharide polymer, are 70% more prevalent in colostrum than in mature milk and are known as a prebiotic for their tendency to bind to the epithelium of the small intestine, prevent pathogen adhesion, and promote the growth of beneficial bacteria (Fischer-Tlustos et al., 2020). Oligosaccharides have also been seen to reduce the expression of inflammatory cytokines and decrease intestinal inflammation in mice (Ewaschuk et al., 2008), leading to a localized immunity in the small intestine. Lactoferrin is a protein known for its iron-binding and antimicrobial properties (Robblee et al., 2003; Turin et al., 2014) and is seen in nine times greater concentration in colostrum than in mature milk (Sánchez et al., 1988). Studies conducted looking at the supplementation of lactoferrin in calf diets have found that feeding greater concentrations in the diet leads to reduced fecal scores (where lower numbers correspond to a fecal consistency closer or equivalent to normal), fewer number of days medicated for gastrointestinal issues, and reduced death loss from diarrhea (Robblee et al., 2003; Prenner et al., 2007; Habing et al., 2017). Though the exact mechanism of this effect is not well-established, one study also found that supplementing lactoferrin increased the concentration of Ig secreted into the small intestine, which likely adds to the effects of localized immunity in the gut (Prenner et al., 2007). Another set of bioactive compounds found in colostrum are insulin, which is found at a concentration of approximately 325 ng/mL in colostrum but only 46 ng/mL in mature milk (Aranda et al., 1991), and insulin-like growth factor-I and -II, which are seen at concentration ranges of 50-2000 ng/mL and 200-600 ng/mL, respectively, compared to <10 ng/mL in mature milk (Pakkanen and Aalto, 1997). Both insulin and insulin-like growth factors are thought to stimulate intestinal growth by increasing the height of ileal villi, which increases the surface area of the intestinal lining and allows for greater nutrient and Ig absorption, leading to a greater chance for successful transfer of immunity from dam to calf as well as a greater supply of macronutrients for energy, growth, and thermoregulation (Blum and Hammon, 2000; Hare et al., 2023). Further, maternal cytokines and leukocytes have also been seen in high concentration in colostrum (Mohr et al., 1970; Hagiwara et al., 2000). Cytokines and leukocytes are both absorbed from colostrum into the calf's circulation through the intestinal epithelium and may enhance the development of the neonate's immune system by strengthening the calf's lymphocytes' response to mitogens and increasing phagocytosis (Godden, 2008; Gonzalez and Santos, 2017).

Lastly and arguably most importantly, the most discussed bioactive compound seen in increased concentration in colostrum compared to mature milk are immunoglobulins (Igs), recognized as the primary immune component present in colostrum (Stelwagen et al., 2009). Igs appear at concentrations of approximately 59 mg/mL in colostrum, compared to the almost negligible concentration of 0.8 mg/mL seen in mature milk. The most common Igs found in colostrum are IgG, IgA, and IgM, which comprise approximately 85-90%, 5%, and 7% of all Igs in colostrum (Larson et al., 1980). IgG is further broken into two subclasses, where approximately 80% is IgG_1 and 20% is IgG_2 (Gapper et al., 2007). The average concentrations of IgG_1, IgG_2, IgA, and IgM in maternal colostrum are 35 mg/mL, 6 mg/mL, 1.7 mg/mL, and 4.3 mg/mL, respectively (Kehoe et al., 2007). Immunoglobulin G (IgG) functions to detect the presence of pathogens, bind to them, and eventually inactivate or neutralize them (Butler, 1969; Vlasova and Saif, 2021; Lopez and Heinrichs, 2022a). Functionally, the absorption of IgG has also been associated with lower rates of disease and increased development of calf antibodies (Villouta et al., 1980; Besser et al., 1988). Due to its high prevalence in colostrum, as well as its high relative abundance in the calf's blood serum following ingestion of adequate colostrum, it is often used as the primary measure of the success of immune transfer from dam to calf (Berteselli et al., 2024).

While the role of IgG in the development of the immune system of neonatal calves is widely understood, the role of other immunoglobulins, such as IgA and IgM, is less frequently discussed. One study looking at the effects of IgA showed that piglets fed colostrum with increased concentrations of IgA had decreased bouts of diarrhea compared to those receiving a lower concentration of IgA, which was thought to be caused by the creation of localized immunity in the small intestine by IgA (Bohl et al., 1975). More recent studies have theorized that secretory IgA in the small intestine of calves has a similar effect of localized immunity, as well as additional prebiotic effects in the gut (Răducan et al., 2012; Villot et al., 2020). Further, early research proposed that IgM was better at agglutination, phage neutralization, complement fixation, and hemolysis than IgG (Butler, 1969); IgM is now identified as being responsible for identifying and destroying bacteria in the bloodstream due to its strengths in fighting septicemia and facilitating agglutination (Lopez and Heinrichs, 2022a). IgE is also present in bovine colostrum and has been theorized to aid in protection against intestinal parasites, but the role of it in the development of calf immunity is still unknown (Thatcher and Gershwin, 1989). Regardless, all Igs found in colostrum work together in the body to identify and target pathogens and serve as the foundation for the development and maturation of the neonate's immune response.

1.4 Transfer of Passive Immunity

All calves are born with a naïve immune system and rely on the intake of maternal colostrum to develop their immune systems further (Larson et al., 1980). When the bioactive compounds found in the maternal colostrum, primarily Igs, are fed to calves and absorbed into circulation, this is referred to as a transfer of passive immunity (TPI) from dam to calf (Lombard et al., 2020). The primary compound involved in TPI is IgG (Butler, 1969), as it makes up 85-90% of all Igs found in colostrum (Godden et al., 2019). Maternal IgG is absorbed by the calf through a specialized process involving the apical tubular system of intestinal absorptive cells (Bush and Staley, 1980). This process occurs only for approximately the first 24 hours after birth when macromolecules are transported via active pinocytosis from the intestinal epithelium to lymph tissue and eventually into systemic circulation through the thoracic duct (Besser and Gay, 1994; Quigley, 2005). Some evidence suggests a cellular preference for species-specific IgG transport, which would require specific receptors such as FcRn to transport the immunoglobulin proteins rather than broad and nonspecific protein absorption (Stott et al., 1979; Wild et al., 1994). Fc-receptors, glycoproteins that aid in immunity by binding to the Fc region of immunoglobulins to help aid in absorption and upregulate immune function (Gessner et al., 1998), had not previously been identified in calves; However, recent evidence shows colocalization of IgG with the neonatal

Fc-receptor (FcRn) in the intestinal villi, indicating its potential role in IgG transport in neonatal calves (Jochims et al., 1994; Sangild, 2003; Hiltz, 2024). These receptors, if present, would bind Igs to vesicle membranes, allowing for protected intracellular transport and safe release of non-digested Ig molecules into the neonate's bloodstream, where they can then be used as part of the immune response (Staley and Bush, 1985). While this absorption occurs all throughout the small intestine, past studies have shown efficiency of absorption increasing from the duodenum to the ileum, with optimal Ig intake and absorption occurring in the jejunum and ileum rather than the duodenum (James et al., 1979). Once the Ig enters the systemic circulation, its functions mimic what is seen in the dam, which is to recognize and neutralize pathogens such as bacteria and viruses that enter the body. When TPI is successful, the passive immunity from the dam will remain effective until the calf's own immune system matures enough to produce and secrete its own Igs, at which time the maternal Igs will begin to breakdown and be replaced by the calf's Igs present (Barrington and Parish, 2001).

The success of TPI can be determined by measuring calf serum IgG concentrations using radial immunodiffusion (RID) assays, by measuring calf serum total protein concentrations using hand-held refractometers, or by measuring %Brix -a reflection of total solids percentage- using digital refractometers between 24-48h of age (Weaver et al., 2000; Deelen et al., 2014). On an individual calf-basis, the cutoff for declaring failed transfer of passive immunity (FTPI) is a serum IgG concentration of <10 g/L, which corresponds to a serum total protein concentration of <5.1 g/dL and a Brix value of <8.1% (Godden et al., 2019; Lombard et al., 2020). However, due to variability in measurements of serum total protein and %Brix, serum total protein values of <5.0-5.5 g/dL and %Brix values of <8.1-8.5% have commonly been used as cutoff values for FTPI (Godden et al., 2019). On a herd-level basis, it is recommended that over 40% of calves have serum

IgG concentrations in the excellent category (≥25 g/L), approximately 30% of calves in the good category (18.0-24.9 g/L), approximately 20% of calves in the fair category (10.0-17.9 g/L), and less than 10% of calves in the poor category (<10 g/L), where calves in the poor category are said to experience FTPI, which puts them at greater risk for disease and decreased productivity later in life (Lombard et al., 2020). According to a USDA National Animal Health Monitoring System (NAHMS) heifer calf study conducted in 2014, 35.5%, 25.7%, 26.8%, and 12.0% in the excellent, good, fair, and poor categories, respectively, suggesting a slightly elevated herd-level presence of FTPI across replacement calves in the United States (Lombard et al., 2020; USDA NAHMS, 2022). Another study reported the average calf-level prevalence of FTPI for replacement heifers in the United States to be approximately 19.2% (Beam et al., 2009), which is still slightly elevated beyond recommendations. However, when looking at non-replacement calves, calf-level FTPI prevalence rates have been seen as high as 43% in some herds (Stilwell and Carvalho, 2011; Creutzinger et al., 2021). FTPI has been associated with increased morbidity of respiratory disease and diarrhea, increased neonatal mortality rates, decreased growth rates, and decreased overall productivity (Weaver et al., 2000; Windeyer et al., 2014a; Urie et al., 2018).

In order to prevent FTPI in calves, colostrum management on the source dairy must meet all industry recommendations for quality, quantity, timeliness of feeding, and cleanliness. The quality of colostrum refers to the concentration of IgG in the colostrum sample being fed. Current literature recommends that calves receive 300g of IgG total shortly after birth, with the concentration of colostrum in each feeding being ≥ 50g/L (Godden et al., 2019). A Brix refractometer can be used to sample the colostrum being fed to determine its quality, with recommendations of >25% Brix for the first feeding and/or ≥ 23% Brix for the second feeding (Godden et al., 2019; Cramer, 2025b). To reach the 300g total of IgG, calves must be fed approximately 6L of high-quality colostrum, ideally split between 2 feedings to not overwhelm the neonate's stomach. To account for fluctuations in birth weight and sizes of the animals at birth, the most common suggestion is to feed calves roughly 10% of their body weight in colostrum for their first feeding (3-4L for most Holstein calves and 4L for most beef-on-dairy cross calves), then to feed the rest within 24 hours of life. One study suggests that calves had adequate serum IgG when they were fed 4L of colostrum at 0h after birth and an additional 2L at 12h after birth (Morin et al., 1997), however some producers will provide up to 4L during the second feeding to ensure adequate IgG absorption. Recent work by Sockett et al. (2023) shows that this high volume of colostrum feeding can lead to severe digestive upset due to underdevelopment of the stomach at birth and suggests feeding a lower volume (2-3L) colostrum instead (Sockett et al., 2023). A study by Conneely et al. (2014) showed that calves fed 8.5% of their body weight in colostrum had much higher rates of IgG absorption when compared to calves fed 7% and 10% of their body weight (Conneely et al., 2014), so feeding high volumes of colostrum to calves at birth could actually be hindering the efficiency of absorption of these key immune proteins. Further, Sockett et al. (2023) reports that most neonatal Holstein heifers will not drink more than 2L of colostrum on their own, meaning anything over that volume would need to be fed via esophageal tube feeder, which can cause further issues such as aspiration pneumonia and tracheal trauma. Thus, the most recent recommendation put forth by Sockett et al. (2023) is to feed a lower volume of colostrum overall. However, in order to ensure calves are still receiving > 300g IgG within 12-24 hours after birth, Sockett et al. (2023) also recommends feeding a higher quality of colostrum averaging ≥ 75 g/L (≥ 25% BRIX). A past study by Conneely et al. (2013) analyzed factors associated with colostrum IgG concentrations in dairy cows, and in doing so reported an average IgG concentration of 112 g/L and a range of 13 to 256 g/L across over 700 cows of varying breeds and parity groups

(Conneely et al., 2013). Therefore, providing colostrum that has at least 75 g/L of IgG should be easily attainable. However, one study conducted in 2010 by Morrill et al. showed that, across 67 dairy farms in 12 different states, the average IgG concentration in maternal colostrum was 68.8 g/L, with a range of < 1 to 200 g/L (Morrill et al., 2012). While this is sufficient to meet current industry guidelines of > 50 g/L (Godden et al., 2019), it is insufficient to meet recommendations put forth by Sockett et al. (2023) and would therefore need to be supplemented to maintain adequate amounts of IgG delivered to neonates if volumes of colostrum fed at birth are to be decreased.

The timing of colostrum feedings is equally as important to the success of TPI, as the absorption rate of IgG begins to decline rapidly beginning at 12h postpartum until near complete cessation of absorption occurs around 24h postpartum due to a phenomenon termed “gut closure” (Stott et al., 1979). Thus, the colostrum must be fed in adequate quality and quantity within the first 24h of life, with the more ideal timeline being prior to 12h of life. Further, apparent efficiency of absorption (AEA) of IgG has been seen to decrease as the time between birth and the first colostrum feeding increases (Bush and Staley, 1980). For instance, one study shows that delaying the first feeding of colostrum to 6h postpartum led to decreased AEA of IgG by approximately 16% compared to those fed colostrum immediately after birth (Fischer et al., 2018). Further, a study by Hiltz (2024) found that calves fed the first feeding of colostrum within one hour after birth were able to continue absorbing IgG into the bloodstream at 24 hours of life, whereas those that missed the first feeding of colostrum had lost the ability to absorb IgG 24 hours of life (Hiltz, 2024). The current recommendation states that producers should aim to provide the first feeding of colostrum within 1-2h postpartum, and the second within the first 12h of life (Godden et al., 2019).

Lastly, in addition to controlling colostrum quality, quantity, and quickness of delivery, it is important to minimize the bacterial load of the colostrum being fed, as the neonates will have no immune response to battle any pathogens at birth and the presence of bacteria in colostrum has been seen to reduce AEA of IgG (Johnson et al., 2007; Godden et al., 2012). Poor udder hygiene and unclean equipment during colostrum collection can result in high pathogen loads. To minimize this risk, all equipment and buckets should be sanitized between collections, raw colostrum should not be pooled, and colostrum should only be collected from healthy cows with clean, uninfected udders (Godden et al., 2019). Pathogen load can also increase during improper storage, so if colostrum is not going to be used immediately after collection, it should be either pasteurized before feeding, preserved with potassium sorbate and refrigerated, or frozen if stored for more than 2 hours post-collection (Patel et al., 2014; Godden et al., 2019). Testing of colostrum for overall cleanliness prior to feeding it to neonates is recommended as a routine monitoring tool (McGuirk and Collins, 2004; Godden et al., 2019). To test, colostrum should be sampled and plated to determine total plate counts (TPC), representing the overall bacterial load. Currently, farmers are recommended to only use colostrum that has a TPC < 100,000 cfu/mL (McGuirk and Collins, 2004). Additionally, it has been previously discussed that non-replacement calves often receive a poorer quality and/or lower volume of colostrum, as well as often receiving it later in life (>2h postpartum) compared to replacement heifers. All these factors point toward poor colostrum management for non-replacement calves, which in turn will lead to poor IgG absorption and increased rates of FTPI in these calves.

When maternal colostrum of adequate quality and quantity are not available, using powdered colostrum replacer (CR) in place of and/or in addition to maternal colostrum has recently been studied as a potential solution. According to one study, using CR allows for more uniform and precise quality and cleanliness measures, as they are created with a set concentration of IgG and minimizes pathogen transmission from the dam (Godden et al., 2019). However, studies conducted by the USDA National Animal Health Monitoring System (2014) and by Lago et al. (2018) report lowest concentrations of serum IgG among calves fed CR when compared to those fed maternal colostrum from cows in various parity groups (USDA NAHMS, 2022; Lago et al., 2018). Colostrum replacers can be a helpful supplement to maternal colostrum in cases where volumes and/or quality (IgG concentrations) of maternal colostrum are not adequate to support all calves in the herd, however adding CR to maternal colostrum can impact the osmolality of the diet fed and lead to increased digestive issues (Glosson et al., 2015). Thus, utilizing colostrum replacer can be helpful in some cases, but is not recommended as a full-time solution for poor colostrum management and should be used in careful consideration of total solids concentration in the diet of neonates.

1.5 Feeding Colostrum Following Gut Closure

As mentioned in previous sections, morbidity and mortality remain an issue during the preweaned period, regardless of the success of TPI. The two most common diseases affecting cattle in this time are bovine respiratory disease (BRD) and diarrhea, with past research showing over 5% of non-replacement calves and roughly 17% of replacement heifers exhibiting signs of BRD and nearly 67% % of non-replacement calves and roughly 9% of replacement heifers exhibiting signs of diarrhea (USDA NAHMS, 2022; Pereira et al., 2024). Further, calf-raising facilities across North America and Europe, regardless of whether it is a dairy or beef calf ranch, have a 3-8% mortality rate for calves in the preweaned period (Bähler et al., 2012; Pardon et al., 2012; USDA NAHMS, 2022; Winder et al., 2016; Renaud et al., 2018b; Goetz et al., 2021). The impacts of colostrum feeding and management on overall health, often defined by success or failure of the transfer of passive immunity, are well documented. However, in recent years, animal scientists have begun to explore other nutritional interventions that may improve health during the preweaned period following the feeding of colostrum. When looking at improving the plane of nutrition during milk feedings, researchers found that improving volumes of milk fed and/or total solids concentrations in the milk have positive impacts on heart rate variability and therefore stress responses, but negative impacts on incidences of diarrhea (Glosson et al., 2015; Scoley et al., 2019). However, one study looked specifically at increasing the amount of fat fed in the milk diet and found that calves fed milk with lower amounts of dietary fat had more than three times the odds of mortality compared to those fed a higher fat diet (Urie et al., 2018). Additionally, scientists have found that certain feed additives such as lactoferrin, prebiotics, and probiotics can help decrease the number of calves culled within the first 120 days of life, lower the risk of pathogen colonization in the gut, reduce the number of diarrhea bouts per calf, and decrease the number of treatment days overall (Habing et al., 2017; Cangiano et al., 2020). One group studying the effects of feeding transition milk following colostrum feedings, rather than switching directly to whole milk or milk replacer, reported that calves receiving transition milk had lower odds of eye or ear abnormalities as well as lower odds of having nasal discharge (Conneely et al., 2014). While no one strategy has been identified as the most effective at reducing morbidity and mortality in preweaned calves, it is well understood that the diet of these animals plays a key role in health and productivity throughout the remainder of their lives.

An additional dietary intervention that has become increasingly popular in recent research is extended colostrum feeding (ECF) programs, where additional colostrum is supplemented into the diet of calves following the period of gut closure, which is 24 hours of age according to older studies (Bush and Staley, 1980; Jochims et al., 1994) and current industry dogma. Previously, researchers had believed that efficiency of absorption of IgG in the small intestine decreases quickly after birth until finally ceasing at or around 24 hours of age (Stott et al., 1979; Bush and Staley, 1980). However, one recent study discovered that calves' capacity for transporting IgG across the intestinal epithelium did not differ between 0h and 24h of life, among those that received their first feeding prior to 1h of life (Hiltz, 2024), meaning that if the first feeding of colostrum is delivered in a timely manner, additional IgG fed in colostrum following 24h of age could still be absorbed and be able to provide immune benefits to the calf. Further, little is known about the timeline of absorption effectiveness for bioactive compounds found in colostrum other than Igs, so there could be a larger window of absorption for other immune boosting compounds that would be utilized by increased consumption duration through ECF programs (Snodgrass et al., 1982). In addition, the increased concentration of bioactive immune compounds in colostrum compared to regular milk could help in improving localized immunity in the small intestine even after the cessation of absorption (Prenner et al., 2007; Ewaschuk et al., 2008). Providing additional colostrum, therefore prolonging the number of feedings the calves receive with increased concentrations of immune compounds, is consistent with what the calf would naturally experience if it were to be left in contact with the dam. Lactating cows naturally produce transition milk for up to five days following production of colostrum prior to the production of regular milk; Transition milk is known to contain concentrations of immune compounds that are in between that of colostrum and regular milk (Abd El -Fattah et al., 2012; McGrath et al., 2016), which is mimicked by the addition of supplemental colostrum to milk-based diets seen in ECF programs. Past studies have shown that when transition milk is collected from cows and fed to calves following proper colostrum delivery, calves have reduced frequency of diarrhea, lower instances of nasal or ocular discharge, and increased development of intestinal villi when compared to calves that received only whole milk or milk replacer following proper colostrum delivery (Conneely et al., 2014; Pyo et al., 2020; Kargar et al., 2021; Van Soest et al., 2022). Overall, feeding transition milk to calves more closely follows natural behaviors and has been reported to improve early-life health outcomes and increase development of the neonatal digestive system. However, adding additional management steps of collecting, processing, storing, and effectively delivering maternal transition milk could be challenging for some producers. Thus, recent research has examined how providing additional feedings of stored maternal colostrum or supplementing milk diets with colostrum replacer for several days after birth affects calf health and development.

One of the earliest ECF studies found that calves fed colostrum for six feedings had significantly larger small intestinal villi compared to those only fed colostrum for one feeding (Bühler et al., 1998). A more recent study found that feeding a 1:1 colostrum to milk replacer ratio for three days postnatal led to increased serum Insulin Growth Factor-1 (IGF-1) and increased development of the small intestine compared to those only being fed whole milk (Pyo et al., 2020). This is consistent with previously described findings in studies analyzing the impact of transition milk on intestinal development. Increased surface area of intestinal villi and more developed small intestines increase the potential for absorption of nutrients and beneficial compounds from the diet (Blum, 2006), lending itself to the possibility of continued IgG absorption efficiency in calves even after the first day of life. The absorption of digestive nutrients as well as immune proteins will aid the calf in improving growth and development of its natural immune system (Blum and Hammon, 2000).

Due to this relationship between colostrum supplementation and intestinal development, ideally leading to improved immunity, there have been numerous studies exploring the potential impacts of ECF programs on the morbidity and mortality in preweaned calves. This area of research started gaining traction when Snodgrass et al. (1982) explored the effects of leaving calves with their dams until 48h of age, then either feeding whole milk only, whole milk with 10% maternal colostrum supplementation from dams not vaccinated for rotavirus, or whole milk with 10% maternal colostrum supplementation from dams that had been vaccinated for rotavirus until 14d of age (Snodgrass et al., 1982). The authors found that calves fed colostrum had decreased diarrhea severity compared to those fed only whole milk, and that calves fed colostrum specifically from dams vaccinated for rotavirus had decreased fecal indices and decreased number of days with diarrhea compared to the other two treatment groups (Snodgrass et al., 1982). In the dairy industry today, it is recommended that all adult dairy cows are vaccinated for rotavirus 40-60 days prior to calving (Waldner et al., 2017), so it can be assumed that most or all maternal colostrum today is coming from vaccinated dams. A few years later, Nocek et al. (1984) decided to explore the effects of supplementation of maternal colostrum for those calves receiving low quality initial colostrum (<45 mg/mL of IgG), and determined that supplementation of colostrum actually led to increased number of diarrhea bouts and increased number of fever bouts compared to calves receiving poor initial colostrum followed only by milk replacer (Nocek et al., 1984). However, the authors did note that the increase in diarrhea and fever bouts were likely due to the increased total solids of the supplemented colostrum, likely leading to osmotic diarrhea. Over two decades later, Berge et al. (2009) decided to research the effects of supplementing additional milk replacer or colostrum replacer on the health of calves specifically within the first 28 days of life (Berge et al., 2009). In this study, calves either received 0g milk or colostrum replacer (control), 70g milk replacer (MR), or 70g colostrum replacer (CR) containing 14.3% IgG added to their traditional diet for 0-14d of age; The authors discovered that those fed CR had decreased diarrhea bouts and number of antibiotic treatments compared to control and MR calves, meaning the ECF program had positive effects on the health of the animals during this period (Berge et al., 2009). However, one limitation of this study is that it only followed calves for the first 28 days of life, which is prior to the known age where respiratory disease morbidity tends to spike in dairy calves. Therefore, in a future study, Chamorro et al. (2017) increased the experimental ECF dosage to 300g CR per day for 1-14d of life and followed them through 56d of life (Chamorro et al., 2017). Chamorro et al. found that calves in the ECF program, those receiving supplemental CR, had decreased odds of abnormal respiration, decreased diarrhea bouts, and decreased number of treatment days compared to control calves (Chamorro et al., 2017). In a continued exploration of ECF programs, Kargar et al. (2020) explored the effects of different dosages of pasteurized maternal colostrum (MC) supplemented to the milk by randomly assigning calves to one of three diets: 5kg MR + 0g MC (control), 4.65kg MR + 350g MC, or 4.3kg MR + 700g MC. The authors found little difference in health outcomes between calves receiving 350g and 700g of MC but did see that those receiving 700g MC had decreased incidence of pneumonia and diarrhea compared to control calves (Kargar et al., 2020). Another study by McCarthy et al. (2024) experimented with both colostrum dosage and duration of ECF programs by feeding calves one of four diets: 450g MR from d2-14 (control), 380g CR + 225g MR from d2-3 followed by 450g MR from d4-14 (transition ECF), 45g CR + 450g MR from d2-14 (true ECF), or 380g CR + 225g MR from d2-3 followed by 45g CR + 450g MR from d4-14 (transition + true ECF) (McCarthy et al., 2024). There was no overall effect of diet on respiratory distress or number or duration of diarrhea bouts, but calves fed the transition or true ECF diets did have a reduced risk of diarrhea compared to control calves from 0-21d of age (McCarthy et al., 2024). This study highlights potential benefits of frontloading additional colostrum within the first few days following gut closure rather than feeding it in low doses over the first two weeks. Lastly, a recent publication by Wang et al. (2025) set out to explore the effects of and ECF program broken out by the calves' success with transfer of passive immunity, as determined by serum total protein levels. Wang et al. (2025) were able to determine that, though ECF did not have an overall impact on calf health, among calves with FTPI, those fed MR containing 18% CR for the first 21d of life had reduced incidence of diarrhea compared to those receiving only MR. While there is some disagreement among studies, there seems to be an overall positive effect of ECF programs on preweaned calf health. However, further research is needed to determine the ideal concentration of colostrum to feed and ideal duration of the ECF program to maximize health outcomes.

While improving morbidity and mortality in preweaned calves is a major focus in the industry, it was not the only focus of past ECF research. A few studies also analyzed the effects of prolonged supplementation of colostrum replacer in the diet on the growth, intake, and feed efficiency of these animals. For example, Nocek et al. (1984) found that supplementation of colostrum replacer for those that initially received poor quality colostrum led to increased dry matter intake from liquids and increased weight gain from 5 to 45 days of age (Nocek et al., 1984). Robblee et al. also discovered positive linear correlations between concentration of supplemented lactoferrin in the diet, a key biological immune compound found in colostrum, and both average daily gain (ADG) and feed efficiency (Robblee et al., 2003). Further, the previously mentioned studies conducted by Berge et al. (2009) and Kargar et al. (2020) also found improved average daily gain among calves enrolled in their ECF treatments compared to those in their control treatments (Berge et al., 2009; Kargar et al., 2020a). Lastly, while the study conducted by McCarthy et al. (2024) found no overall impact of the ECF treatments on average daily gain, the authors did notice a treatment by time interaction such that calves receiving supplemental colostrum had greater average daily gain during week 3 of life compared to those that received only milk replacer (McCarthy et al., 2024). In summation, past research has shown positive impacts of supplementing colostrum beyond the first day of life on calves' intestinal development, overall health outcomes, and growth during the preweaned period.

As colostrum management continues to improve and rise in popularity among conversations in the dairy industry, ECF programs may be able to be used more specifically to target those calves that do not receive adequate IgG through initial colostrum feedings and subsequently experience FTPI. Therefore, one group that might especially benefit from ECF programs would be non-replacement calves, since they often are still receiving lower quality and quantity, as well as poorer timing, of first colostrum feedings before being exposed to transportation stress. Implementing ECF programs for non-replacement calves once they arrive at calf ranches could help improve morbidity and mortality rates. However, no studies have yet been done specifically looking at the impact ECF programs could have on non-replacement calf health or growth, though it is expected that the impacts of ECF on non-replacement animals will follow trends seen in past research conducted on replacement heifers. Additionally, little is known about how implementation of an ECF program could impact lying behavior, which is a key indicator of how comfortable an animal is in its environment (Bonk et al., 2013). Improving both health and comfort of non-replacement animals would significantly improve their overall welfare and productivity later in life (Murray et al., 2016; Mattiello et al., 2019; Buczinski et al., 2021; Machado and Ballou, 2022), making it beneficial to both the calves and the producers raising them.

1.6 Knowledge Gap - Calf Lying Behavior

To determine the quality of welfare an animal is experiencing throughout its life, one could observe and analyze the physiological characteristics the animal is exhibiting, such as pain, illness, growth rates, appetite, or even body condition. However, another key component of animal welfare is the animal's behavior, as it can provide insight into those aspects of living and of welfare which are not always easily seen or understood through health or growth metrics (Mench, 1998). In fact, as proposed by McCausland (2014), when analyzing welfare on the basis of the Five Freedoms of Animal Welfare, only two of the five basic freedoms that should be awarded to all animals – The Freedom from Hunger and Thirst and The Freedom from Pain, Injury and Disease – can be analyzed based on health and growth metrics alone (McCausland, 2014). The other three freedoms that McCausland (2014) states all animals should be awarded – Freedom from Discomfort, Freedom to Express Normal Behavior, and Freedom from Fear and Distress – are instead better measured through behaviors such as lying or standing time, presence of stereotypies, vocalization, motivation, and avoidance behaviors (Mench, 1998; McCausland, 2014). It is well understood that animals use their behavior as a way of communicating (Smith, 1977), and it is part of the job of livestock producers to understand the messages their animals are sending through their behavioral patterns. For example, a cow bellowing on an otherwise quiet dairy farm could be an indicator of pain or distress, even if she appears to be otherwise healthy (Grandin, 1998; Manteuffel et al., 2004). Thus, behavior is often measured in addition to health and growth metrics in research and on-farm observations to help better explain the quality of an animal's overall welfare.

One such behavior that can be useful in the study of dairy calves and their welfare is lying behavior. During their first eight weeks of life, dairy calves spend 65–80% of their time, approximately 16 to 19 hours per day, lying down (Panivivat et al., 2004; Wojciech et al., 2017). Calves that rest less than expected may be experiencing stress, either as a cause or consequence of reduced lying time. Thus, calf lying behavior has been explored by many previous researchers as an important indicator of overall calf welfare in terms of calf comfort (Bonk et al., 2013) and calf health (Zhang et al., 2024). According to the "Three Circles" framework of animal welfare, originally proposed in 1997 and revised in 2009 by David Fraser (Fraser et al., 1997; Fraser, 2009), animal welfare is a multifaceted metric determined by the animal's ability to adequately perform in each of three areas: Basic Health and Biological Functioning, Positive Affective States, and Natural Behaviors. A young calf's ability to lie down for an adequate proportion of time is a natural behavior that occurs when a calf is healthy and comfortable and can change significantly in response to pain, disease states, or distress. For these reasons, lying behavior falls under both the Basic Health and Biological Functioning and Positive Affective States circles and therefore is an important factor to consider when analyzing the overall impact certain management factors may have on an animal's welfare. While there are other validated behaviors that also indicate pain or distress in an animal, such as altered feeding behaviors, decreased play behaviors, or increased stereotypic behaviors (Krohn et al., 1999; Overvest et al., 2016), lying behavior is especially important to measure as it makes up the majority of a young calf's time budget and is easier to capture compared to other behaviors due to validated automated logging devices (Ledgerwood et al., 2010; Bonk et al., 2013).

When conducting lying behavior research, it is important to understand that lying behavior is influenced by many factors, including intrinsic factors such as age, sex, breed type, birth weight, and season of birth (Riley et al., 2023) as well as external factors such as nutrition (Rufino et al., 2019; Scoley et al., 2019), disease states (Borderas et al., 2008), and external stressors (Kovács et al., 2018; Ruiz, 2019; Bajus et al., 2023). Much of the recent research conducted on calf lying behavior has focused on its relationship with disease states, aiming to determine whether changes in lying patterns could serve as early indicators of illness before clinical symptoms appear (Belaid et al., 2020). There is general agreement among studies that calf lying behavior does significantly change prior to the onset of clinical signs of illness, but the degree to which behavior changes has been a topic of disagreement among recent findings. Table 1.1 summarizes the findings of nine different studies exploring the effect of disease states, including respiratory disease, diarrhea, elevated temperature, and combinations of these states, on calf lying behavior. Of these nine studies, three identified an increase in overall lying time (Duthie et al., 2021; Goharshahi et al., 2021; Zhang et al., 2024), two identified a decrease in overall lying time (Studds et al., 2018; Swartz et al., 2020), and three saw no change in overall lying time between sick and healthy calves (Borderas et al., 2008; Lowe et al., 2019; Belaid et al., 2020). Additionally, two of the nine studies identified an increase in number of lying bouts per day (Swartz et al., 2020; Zhang et al., 2024) while four identified a decrease in number of lying bouts per day (Studds et al., 2018; Sutherland et al., 2018; Lowe et al., 2019; Belaid et al., 2020). Lastly, three of the nine studies identified an increase in average duration of each lying bout (Borderas et al., 2008; Lowe et al., 2019; Duthie et al., 2021), two identified a decrease in average bout duration (Swartz et al., 2020; Zhang et al., 2024), and one reported no difference in average bout duration between sick and healthy calves (Studds et al., 2018). Differences in these studies could be due to diseases included in the definition of "sick" animals, disease detection method, and method of tracking lying behaviors, or some combination of these factors. Further research is still needed to more clearly explain the effects disease states can have on calf lying behavior. Regardless, disease states impact lying behavior in some way, which in turn would impact calf comfort and overall welfare.

In addition to disease, nutritional interventions can have an influence on calf lying behavior during the preweaned period. Past studies have explored the impact of colostrum feeding methods (suckling vs. esophageal tube feeding vs. nipple feeding vs. open bucket feeding) and saw little to no effects on lying, resting, or sleeping habits (Hänninen et al., 2008; Lundmark, 2016). No studies explore the effects of the amount of colostrum fed or timing of colostrum feeding on lying behavior, though some studies do explore this in terms of feeding and social behaviors. One study explored the effects of adding CR to maternal colostrum during initial feedings to boost the nutritional content and saw no difference in lying behavior (Knauer et al., 2025), but a different study reported an increase in time spent lying correlated with an increase in total solids of the milk fed to Holstein heifers (Rufino et al., 2019). The increased total solids provided to calves by the added CR in ECF programs, combined with the propensity of ECF programs to reduce disease states, could lead to an overall improvement in lying behavior caused by the implementation of ECF programs. However, there are currently no published studies exploring the effects of ECF programs on lying behavior in pre-weaned non-replacement dairy calves. Thus, a study should be conducted to directly explore the effects of ECF programs on the lying behavior of calves to see if supplementing colostrum beyond the first day of life affects lying behavior.

1.7 Conclusion

Non-replacement dairy calves, those born on a dairy but sold into the beef supply chain due to being unfit to replace the milking herd (Cramer et al., 2024), have been known to receive poorer colostrum management on their source dairies (Renaud et al., 2017; Shivley et al., 2019; Creutzinger et al., 2021), leading to higher rates of failed passive transfer of immunity compared to replacement calves (Beam et al., 2009; Stilwell and Carvalho, 2011; Creutzinger et al., 2021). Failed passive transfer can lead to increased morbidity and mortality as well as decreased growth (Windeyer et al., 2014a; Urie et al., 2018; Lombard et al., 2020), both of which are seen in the non-replacement population on a herd-level basis (USDA NAHMS, 2022; Pereira et al., 2024). The effects of the high rates of failed passive transfer from poor colostrum management are also exacerbated by the experience of early-life stressors from transportation to calf-raising facilities at a young age (Vicic et al., 2022; Bajus et al., 2024).

Some nutritional interventions given following the first 24 hours of age have been shown to help improve morbidity and mortality of calves in the preweaned period (Habing et al., 2017; Urie et al., 2018; Cangiano et al., 2020) and could be applied as a solution for non-replacement calves. One such dietary intervention emerging in recent studies is the addition of supplemental colostrum to the diets of dairy calves within the first few days or weeks of life. While the role of colostrum within the first 24 hours of a calf's life is well documented and understood, the welfare benefits of supplementing it in the diet beyond this point are still being researched. Some have found positive associations between colostrum supplementation in the few days of life and overall preweaned calf health and growth (Robblee et al., 2003; Berge et al., 2009; Chamorro et al., 2017; Kargar et al., 2020a), but other recent studies have disagreed (McCarthy et al., 2024; Wang et al., 2025). Further, there is a gap in the knowledge of how supplemental colostrum may benefit overall welfare, as no research has investigated the impact of supplemental colostrum on preweaned calf lying behavior, a key indicator of overall health and comfort (Bonk et al., 2013; Zhang et al., 2024). Given that colostrum supplementation has been linked to improved health outcomes, and improved health has been linked to an increase in lying time (Goharshahi et al., 2021; Zhao et al., 2022; Zhang et al., 2024), supplementing colostrum into the diets of pre-weaned non-replacement calves following the first 24 hours of life could help improve lying time and therefore calves' overall comfort and welfare. Future research is needed to more accurately describe the effects supplemental colostrum has on the health and growth of non-replacement calves, as well as explore the relationship between supplementing colostrum in the diet and overall lying behaviors during the preweaned period.

1.8 Tables and Figures

Table 1.1: *Review of literature on the effect of disease states on calf lying behavior*.

Citation	Effect on Overall Lying Time	Effect on Number of Lying Bouts per Day	Effect on Average Lying Bout Duration
Borderas et al., 2008	*No Change*	*Unspecified*	*Increase*
Studds et al., 2018	*Decrease*	*Decrease*	*No Change*
Sutherland et al., 2018	*Unspecified*	*Decrease*	*Unspecified*
Lowe et al., 2019	*No Change*	*Decrease*	*Increase*
Belaid et al., 2020	*No Change*	*Decrease*	*Unspecified*
Swartz et al., 2020	*Decrease*	*Increase*	*Decrease*
Goharshahi et al., 2021	*Increase*	*Unspecified*	*Unspecified*
Duthie et al., 2021	*Increase*	*Unspecified*	*Increase*
Zhang et al., 2024	*Increase*	*Increase*	*Decrease*

2. PRELIMINARY EXPLORATION OF THE EFFECTS OF EXTENDED COLOSTRUM FEEDING ON CALF LYING BEHAVIOR

2.1 Introduction

One of the primary drivers of dairy calf health is proper colostrum management and delivery. Colostrum is the first milk a dam produces after giving birth, which is rich in antibodies and immunoglobulins essential to immune function (Godden et al., 2019). All calves are born with a naïve immune system, meaning they are incredibly susceptible to disease (Fread, 2023). When these calves receive good quality, clean colostrum, in large enough quantity, and in a timely manner, a transfer of passive immunity (TPI) occurs from dams to the calves, jumpstarting the development of their immune system (Godden et al., 2019; Lopez and Heinrichs, 2022b). Failed TPI is the result of poor absorption of IgG during the period when the gut epithelium is open for absorption, which occurs within the first 24 hours of life (Raboisson et al., 2016; Chamorro et al., 2017). This can be due to low concentration of IgG in the colostrum or feeding the colostrum to the calves too late (Godden et al., 2019). Failed TPI is associated with poor growth, greater risk of disease, greater risk of death, and poor productivity later in life for calves (Furman-Fratczak et al., 2011; Raboisson et al., 2016; Cuttance et al., 2018). Due to this, the dairy industry has placed an intense focus on providing adequate colostrum to neonatal calves, especially to those that will one day enter the milking herd as replacement animals, within the first day of life, significantly decreasing the proportion of heifer calves with failed TPI.

However, previous studies show a discrepancy between colostrum management and feeding for replacement heifer calves and those that are not retained on the source dairy, termed non-replacement calves (Shivley et al., 2019; Creutzinger et al., 2021a). Non-replacement calves are largely comprised of dairy bull calves but also include infertile heifer calves and beef-on-dairy crossbred calves. Shivley et al. (2019) found that on average, bull calves receive 0.7 L less colostrum within the first 24 hours than heifer calves, and they receive their first feeding of colostrum approximately 1.4 hours after heifer calves, both of which fall short of current industry recommendations for colostrum management and delivery (Robbers et al., 2021). Further, bull calves, along with all other non-replacement calves, are often transported long distances to auction markets and/or calf raisers at less than one week old, where they are housed individually and fed a low plane of nutrition (Creutzinger et al., 2021a). The poor colostrum practices coupled with a large number of early-life stressors lead to non-replacement calves having high morbidity and mortality rates (Creutzinger et al., 2021a; Maggard et al., 2024). This becomes a major issue for many reasons, including diminished overall welfare, increased cost of care, and decreased productivity leading to decreased economic value of the animals throughout the remainder of their lives.

One proposed solution designed to improve the overall health of non-replacement calves is to add colostrum replacer to these calves' diets at a low dosage following the initial feeding of maternal colostrum as part of an extended colostrum feeding (ECF) program. Previous studies have explored adding low dosages of colostrum to calf milk replacer for the first 2-3 weeks of life, and have seen decreased morbidity of scours, decreased morbidity of respiratory distress, decreased need for antibiotic therapy, decreased incidence of fever, improved gain and final body weight, and overall improved attitude compared to calves receiving only milk replacer during that same period (Chamorro et al., 2017; Kargar et al., 2020b; McCarthy et al., 2024). While this is still a new field and few publications exist, it appears as though adding colostrum to the diet of neonatal and perinatal calves following gut closure has positive impacts on health and growth. However, no research has yet been conducted detailing the impacts of an ECF program on the behavior of these calves.

Behavior, specifically lying behavior, of calves is a key indicator of rest time and overall calf comfort (Bonk et al., 2013), which are important indicators of positive calf welfare (Mattiello et al., 2019). Both illness and poor nutrition can influence the lying behavior of calves (Wang et al., 2018; Rufino et al., 2019; Belaid et al., 2020). For example, Borderas et al. (2008) show that sick calves have more frequent and longer lying bouts, Swartz et al. (2020) show that they spend less time lying with more frequent but shorter lying bouts, and Zhang et al. (2024) show that they have increased total lying time with more frequent but shorter lying bouts (Borderas et al., 2008; Swartz et al., 2020; Zhang et al., 2024). More specifically, one study of preweaned Holstein veal calves showed that calves experiencing navel inflammation and those experiencing diarrhea had shorter overall lying time compared to healthy calves, meaning the sickness state was diminishing their overall comfort levels (Studds et al., 2018). However, a study by Goharshahi et al. (2021) found that calves diagnosed with diarrhea had longer lying times compared to healthy calves on the day prior to diagnosis (Goharshahi et al., 2021). Similarly, a study by Lowe et al. (2019) found that calves diagnosed with respiratory or digestive issues had fewer lying bouts and increased lying bout duration on the day prior to diagnosis, as well as the days following onset of clinical symptoms (Lowe et al., 2019). While there are inconsistencies in current literature on the way lying behavior changes in response to illness, there is general agreement that lying behavior changes in some way as a response to the onset of disease. In addition to illness, nutrition has also been known to impact lying behavior (De Paula Vieira et al., 2008; Borderas et al., 2009; Rufino et al., 2019). For example, past research has found that calves fed a higher volume or ad libitum volumes of milk had increased lying time and therefore overall comfort compared to those fed a lower or restricted volume of milk (De Paula Vieira et al., 2008; Borderas et al., 2009). Additionally, a study by Rufino et al. (2019) shows that increasing milk total solids, a consequence of supplementing colostrum in the diet, leads to higher calf lying time during the preweaned period compared to those receiving milk with lower percentages of total solids (Rufino et al., 2019). No research has yet been conducted on the impacts of ECF programs on preweaned calf lying behavior. However, given that ECF programs have been seen to influence health, and that health and nutrition are both associated with lying behavior, it is hypothesized that supplementation of colostrum into the milk fed to calves after 24 hours of life could have positive effects on lying behavior and therefore overall calf comfort. Understanding the relationship between ECF programs and lying behavior could inform future studies evaluating the holistic effects of colostrum supplementation on animal welfare. Therefore, the primary objective of the current study was to determine the impact of adding colostrum to fed milk replacer at 10% of the total amount of dry matter intake for the first 14d of life on the lying behavior of pre-weaned dairy calves. Since behavior is an indicator of overall comfort and welfare, which both affects and is affected by calf health and growth, the secondary objective of the current study was to explore the impact of this ECF program on dairy calf health and growth during the pre-weaned period.

2.2 Methods

Data collection for this study took place in Colorado between August and October 2024 on a university research facility that is used to house dairy calves used for hands-on learning in undergraduate animal science courses. The Institutional Animal Care and Use Committee at Colorado State University (6025) approved this study.

2.2.1 Enrollment and Animal Management

Enrollment for this study took place over the course of a week in August 2024. Non-replacement dairy calves (n=26) were enrolled in the study at 1 day of age after being transported 40 kilometers from a local dairy to the university's teaching and research facility. The study period was defined as the time a calf was enrolled until 56 days of age. The research facility had one row of 13 individual pens with dividers in each one to create 26 pens of measurements 1.78 X 4.55m ($8.1m^2$). Pens were initially bedded with pine shavings and straw and were top dressed with straw every two weeks. The facility was ventilated with fans spaced out with one fan every four pens. The pens allowed nose-to-nose contact between adjacent calves. Upon arrival, calves were assigned to a pen using a list of random numbers generated in Microsoft Excel (Microsoft Corp., Redmond, WA) and assigned to one of two treatments: extended colostrum feeding (COL) and control (CON). Calves were assigned to treatment in the order they were unloaded off the trailer and blocked by sex (bull or heifer) and breed (Holstein-Limousin or Holstein) within each group of calves delivered. Treatments were distributed among pens in an alternating pattern so that all odd numbered pens received one treatment, and all even numbered pens received the other treatment. The two researchers that performed all health examinations were blinded to treatment.

All calves, regardless of treatment group, received the first feeding (3.8L) of colostrum (≥22% BRIX) from the source dairy prior to transport to the research facility. Thirteen of the calves received the second feeding (1.9L) of colostrum at the source dairy prior to transport. However, for the other thirteen calves, an inadequate amount of time had passed since the delivery of the first feeding of colostrum to deliver a second feeding at the time they were picked up for transport. Thus, to not overwhelm the digestive tract, the remaining thirteen calves were fed the second feeding of colostrum upon arrival at the research facilities. All calves received the first feeding of colostrum within 1 hour after birth and the second feeding within 24 hours. Blood samples were collected at 48 hours of age and analyzed for serum total protein values to calculate success of passive immunity transfer on a herd-level basis.

Calves in the COL treatment were fed 0.41 kg of powdered milk replacer (Purina Animal Nutrition Land O Lakes Amplifier Max 22:20; St. Louis, MO, USA) added to 2.85L of warm water twice daily with 44g of powdered colostrum replacer (Zinpro® Premolac® Boost; Eden Prairie, MN, USA) added during the morning feeding. Calves in the CON treatment were similarly fed 0.41kg of milk replacer added to 2.85L of warm water twice daily but did not receive the additional colostrum replacer. The added colostrum replacer in the COL group altered the average Brix value, with COL calves receiving milk averaging a Brix value of 14.5% and CON calves receiving milk averaging 12.2%. All calves, regardless of treatment, were fed via bottle from 0-14 days of age and fed via bucket from 14-56 days of age. Calves were gradually weaned starting at 49 days of age by reducing intake by 50% until 56 days of age, when calves were fully weaned. Calves were provided with ad libitum access to grain (Agland Dairy 18% Calf Starter; Parkston, SD, USA), changed daily, and water, changed twice daily, in every pen.

Upon arrival, all calves were weighed and processed, which included ear tagging, navel dipping, and administering intranasal respiratory vaccines (INFORCE 3®; Zoetis, Parsippany, NJ, USA; 2mL/calf). Within 1-5 days of age, all calves received EnterVene®-d (Boehringer Ingelheim Animal Health, Duluth, GA, USA; 4 mL/calf orally) to vaccinate against *Salmonella,* then received a booster two weeks later. Around 3 weeks of age, all calves received a Covexin vaccine (Merck Animal Health, Rahway, NJ, USA; 1.25 mL/calf subcutaneously) to prevent clostridial infections; at 6 weeks of age, all bull calves were given a booster dose of the Covexin vaccine. At 4 weeks of age, all Holstein calves received meloxicam (Unichem Pharmaceuticals, Brunswick, NJ, USA; 45

mg/calf orally) and were dehorned using electric dehorners. All calves also received an additional respiratory vaccine (BOVI-SHIELD GOLD®, Zoetis, Parsippany, NJ, USA; 2 mL/calf subcutaneously) at 4 weeks of age and a booster at 6 weeks of age. All bull calves were castrated at 6 weeks of age using lidocaine-infused castration bands; They received a dose of meloxicam (45 mg/calf orally) 24 hours prior to castration and a second dose (45mg/calf orally) 30 minutes prior to castration for pain mitigation.

2.2.2 Recording Standing and Lying Behavior

Standing and lying behavior were recorded using electronic data loggers (HOBO Pendant G Acceleration Data Logger, Onset Computer Corporation, Pocasset, MA) that were attached to the medial side of the right hind leg of each calf using Vet Wrap (Co-Flex, Andover Coated Products Inc., Salisbury, MA). The loggers were attached according to protocols verified in previous studies (Bonk et al., 2013; Pesenti Rossi et al., 2024). Loggers were placed vertically so that the x-axis was perpendicular to the ground pointing upward, the y-axis was parallel to the ground pointing to the caudal side of the animal, and the z-axis was parallel to the ground pointing toward the midplane of the animal. The loggers recorded the g-force of the x, y, and z-axes at 60 second intervals for 4 days per collection period, for a total of four collection periods at the end of experimental weeks 1, 2, 3, and 7. Since behavior was recorded based on experimental day rather than calf age, animals ranged in age from 2-6 days, 9-13 days, 16-20 days, and 44-48 days old during weeks 1, 2, 3, and 7, respectively.

To ensure minimal interference from students working with the calves on lying behavior, loggers were attached after calves were done being used for teaching for the week and removed before they were used the following week. During the time the loggers were attached, only staff were allowed to enter the pens and only did so when necessary. After the fourth day of each collection period, loggers were removed from the calves and the data were downloaded using Onset HOBOware software (Onset Computer Corporation), which converted the g-force readings into degrees of tilt, then imported into SAS Software (SAS Institute Inc., Cary, NC), which converted the degrees of tilt into number of standing and lying bouts, average standing and lying bout duration (min/bout), and total time spent standing and lying each day (min) (Zobel and Chapinal, 2013). Time spent standing and lying were then converted into proportion of time spent lying per day (min lying/total min in a day) for final analysis.

2.2.3 Health Scores, Weight Measurements, and Thoracic Ultrasonography

Health exams were conducted twice weekly using the UW-Madison Calf Health Scoring Checklist (https://www.vetmed.wisc.edu/dms/fapm/apps/chs.htm). Health examinations included clinical respiratory (CRS; McGuirk and Peek, 2014), fecal, joint, navel, and thoracic ultrasound (TUS; Ollivett and Buczinski, 2016) scores. CRS combined scores from each of the following categories, which were assigned scores on a scale from 0 (normal) to 3 (severely abnormal): nasal discharge, ocular discharge, ear position, cough, and rectal temperature (McGuirk and Peek, 2014). Calves were considered to have clinical respiratory disease when a total respiratory score of five points or higher was observed, provided that at least two categories had a score ≥ 2 (McGuirk and Peek, 2014). Infection in the navel and joints were defined as navel and joint scores ≥ 2, respectively. Fecal scores were recorded on a scale from 0 (normal) to 3 (extremely abnormal) where 0 = fully formed feces, 1 = semi-formed, soft feces, 2 = loose feces that stays on top of bedding, and 3 = water feces that falls through bedding (McGuirk, 2008). Calves were considered to have diarrhea when the fecal score was ≥ 2. Lung ultrasounds were performed using a portable linear rectal ultrasound set at a depth of 9 cm, a frequency of 6.2 MHz, and a gain of 23 dB (near 13 dB; far 36 dB; Ibex Pro, E.I. Medical, Loveland, CO). Isopropyl alcohol (70%, 150mL) was applied to the hair covering the thoracic cavity of the calves as a transducing agent. Both lungs were scanned in a systematic manner, beginning dorsally at the level of the scapula on the right side of the calf in the sixth intercostal space (ICS), moving ventrally within each ICS until specific ultrasonographic anatomical landmarks were identified. Once the landmark was identified within that ICS, the probe was moved cranially to repeat the examination within the fifth through first ICS on the right side. This allowed for examination of the right middle lung lobe, caudal aspect of the right cranial lung lobe, and cranial aspect of the right cranial lung lobe. The process was repeated on the left side of the calf, beginning dorsally at the level of the scapula in the sixth left ICS, moving ventrally within each ICS, and moving the probe cranially to examine up to the second left ICS. This allowed for examination of the caudal aspect of the left cranial lung lobe and the cranial aspect of the left cranial lung lobe. This technique follows what has been previously described in dairy calves (Ollivett et al., 2015; Ollivett and Buczinski, 2016). Normal lung tissue was noted when the hyperechoic line was identified with reverberation artifact, which indicates normal pleural surface (Blond and Buczinski, 2009). Consolidated lung was noted when the tissue appeared hypoechoic and lacked both the hyperechoic line of the pleural surface and the reverberation artifact (Ollivett and Buczinski, 2016; Cramer and Ollivett, 2019). TUS scores were determined after scanning 5 total lung lobes using USS6 examination criteria, which had scores ranging from 0 to 5 (0 = normal or <1 cm^2 consolidation; 1 = diffuse comet tails; 2 = lobular pneumonia: consolidation ≥ 1 cm^2; 3-5 = lobar pneumonia, at least 1 entire lung lobe consolidated). Similar to methods described by Binversie et al. (2020), 95% of the health examinations and TUS were performed by the first author (MMT); the senior author (MCC) performed the remainder. MCC trained MMT in clinical scoring and TUS prior to the start of the study and regularly observed MMT for consistency.

Weights were collected on all calves at the end of each week using a digital scale; Weekly average daily gain (ADG) values were then calculated by taking the difference in weight from the previous week and dividing it by the number of days since the last weight was taken. An ADG value for the entire study period was also calculated at the end of the study by taking the difference between final weight and birth weight to calculate overall gain, then dividing it by the calf's age in days at the time of final weighing. Both total ADG, gain averaged over all days in the study period, and weekly ADG, gain averaged over days in each week of the study period, were included in the final analysis.

2.2.4 Statistical Analysis

Prior to the start of this project, a sample size calculation was conducted based on a mean difference in lying time of 1.1 hours and a standard deviation of 0.838 hours, based on lying behavior determined in a study by Todd et al. (2018). To achieve over 80% power, the minimum sample size per group was 12 calves. However, to account for potential death loss, a total of 26 calves were used in this study with 13 calves per treatment group.

All lying behavior, health, and growth data were stored, cleaned, and collapsed using Microsoft Excel (Microsoft Corp., Redmond, WA) and analyzed using SAS software (SAS Institute Inc., Cary, NC). For all calculations, the experimental unit was the calf, and the primary predictor of interest was the treatment group (CON vs. COL). The primary outcome of interest was standing and lying behavior, but treatment effects on health and growth were also analyzed. All models controlled for breed type and sex, with week as a repeated measure and calf ID as a random effect variable.

Lying Behavior. Standing and lying behavior were defined by proportion of time spent lying throughout the day, number of lying bouts in a day, and average bout duration, all of which were analyzed as either continuous or count data. Three multivariable models were created to evaluate the associations between treatment group (predictor of interest) and the three outcome variables: proportion of time spent lying per day, number of daily lying bouts, and average lying bout duration. The first two outcomes, proportion of time spent lying and number of lying bouts, were analyzed using logistic regression (PROC GLIMMIX) with beta and Poisson distributions, respectively. The third outcome variable, average lying bout duration, was analyzed using linear regression (PROC MIXED). Predicted means for average bout duration were obtained using the LSMEANS statement and adjusted using the DIFF option. For all three outcomes of interest, the final models included treatment, sex, and breed, with experimental day as a repeated measure and calf as a random effect. Estimates from multivariable models are presented as mean ± standard errors, with the associated *P*-values.

Health. Health outcomes included prevalence of fever (rectal temperature score of 3), depressed attitude (attitude score > 0), upper respiratory tract infection (URTI; 2 or more CRS categories with a score of ≥ 2, TUS score < 2), clinical pneumonia (URTI + TUS score ≥ 2), subclinical pneumonia (TUS score ≥ 2 but no URTI), diarrhea (fecal score ≥ 2), navel inflammation (navel score ≥ 2), and joint inflammation (joint score ≥ 2). For all variables 0=no and 1=yes. Associations between treatment and incidence of diarrhea and between treatment and respiratory disease (combined clinical respiratory disease, clinical pneumonia, and subclinical pneumonia) were analyzed using multivariable logistic regressions (PROC GLIMMIX). For both outcomes, the final models included treatment, sex, and breed, with experimental week as a repeated measure and calf as a random effect. Due to health not being a primary outcome of interest, incidences were reported as proportion of calves in each treatment group that experienced at least one bout of the health condition throughout the study period.

Growth. Growth was defined by two outcomes, ADG and feed-to-gain ratios. Average daily gain was calculated during the first two weeks of life, when COL calves were receiving supplemental colostrum replacer, as well as during the entire study period. Feed-to-gain ratios were calculated weekly for both milk and grain intake. Associations between treatment and each of these outcomes were analyzed using multivariable linear regression (PROC MIXED). Predicted means for average daily gain during both time periods and for feed-to-gain ratios for milk and grain were assessed using the LSMEANS statement. For all outcomes of interest, the final models included treatment, sex, and breed, with week as a repeated measure and calf as a random effect. Estimates from multivariable models are presented as mean ± standard errors, with the associated *P*-values.

2.3 Results

There was a total of 26 calves enrolled in this study. Of these, 92.3% (24/26) were beef-on-dairy Holstein-Limousin crosses (BxD) and 7.7% (2/26) were Holstein (Hol); additionally, 42.3% (11/26) were bull calves and the remaining 57.7% (15/26) were heifer calves. All calves were enrolled in the study at <24h of age and left the study at 56-59d of age. According to the serum total protein cut point recommendation of > 5.1 g/dL for determining success of passive immunity transfer, proposed by Lombard et al. (2020), 88.5% (23/26) calves in this study had successful passive transfer of immunity. Of those that had failed passive transfer, one was in the COL treatment and two were in the CON treatment.

2.3.1 Standing and Lying Behavior

Table 2.1 presents the model outputs for the effects of treatment on all calves' lying behavior. There was no association between treatment and proportion of time spent lying, number of daily lying bouts, or average bout duration in the study population ($P > 0.70$). The mean square estimates for proportion of time spent lying 78.8 ±1.5% for CON calves and 79.5 ±1.5% for COL calves ($P = 0.63$). The mean square estimates for number of lying bouts per day were 23.8 ± 1.1 bouts per day for CON calves and 23.7 ± 1.1 bouts per day for COL calves ($P = 0.96$). The mean square estimates for average bout duration were 48.6 ± 1.4 minutes per bout for CON calves and 49.7 ± 1.4 minutes per bout for COL calves ($P = 0.40$). A significant difference ($P < 0.001$) was seen in proportion of time spent lying, number of lying bouts per day, and bout duration across different experimental days when averaging over treatment group (Table 2.2), where time spent lying and number of lying bouts decreased in week 7 compared to weeks 0-2 and average bout duration increased.

2.3.2 Health and Growth of Study Population

Health and growth were measured but did not serve as a primary outcome of interest due to the small sample size. Overall, there were only three incidences of respiratory disease: Two calves, one in each treatment group, presented with subclinical pneumonia and one calf, from the CON treatment group, presented with an upper respiratory tract infection. Overall, the CON treatment group had a higher proportion of calves present with respiratory than the COL treatment group (CON: 15.4%, 2/13; COL: 7.7%, 1/13), but there was no association between treatment and incidence of respiratory illnesses when analyzed in a bivariate analysis ($P = 0.34$; Appendix A). Most of the calves in the study experienced at least one bout of diarrhea during the study period (CON: 100%, 13/13; COL: 92.3%, 12/13). There was no association between treatment and diarrhea incidence (P = 0.18; Appendix A). Overall, very few calves exhibited signs of fever (CON: 15.4%, 2/13; COL: 23.1%, 3/13), navel inflammation (CON: 7.7%, 1/13; COL: 0%, 0/13), or poor attitude (CON: 7.7%, 1/13; COL: 38.5%, 5/13) throughout the study period. In models accounting for breed and sex, the effects of treatment on ADG (kg/d) in the first two weeks, ADG (kg/d) across the whole preweaned period, and feed to gain ratios for both milk (L:kg) and grain intake (kg_{grain}:kg_{gain}) were calculated (Appendix B). Treatment was not associated with ADG within the first two weeks of life (CON: 0.71±0.06; COL: 0.76±0.06; P = 0.39) or throughout the preweaned period (CON: 0.81±0.06; COL: 0.81±0.06; P = 0.88). There was also no association between treatment and feed to gain ratios for milk (CON: 7.06±1.81; COL: 9.07±1.81; P = 0.24) or grain (CON: 0.60±0.12; COL: 0.56 ±0.12; P = 0.74).

2.4 Discussion

Overall, the purpose of the current study was to evaluate effects of an extended colostrum feeding (ECF) protocol on the lying behavior, and therefore comfort and overall welfare, of non-replacement dairy calves during the pre-weaned period. The results of this study indicate no difference in proportion of time spent lying, number of daily lying bouts, or average lying bout duration between current industry protocols for colostrum feeding and an ECF program. However, summary statistics of the current study show the average proportion of time spent lying among all calves to be approximately 78% of the day throughout the preweaned period. This is in line with the activity budget of neonatal dairy calves reported by Pesenti Rossi et al. (2024), which indicated that healthy calves spent 70-80% of their day lying down, as well as with previous behavior studies showing proportion of time spent lying ranging from 70-85% of the day (Chua et al., 2002; Bonk et al., 2016; Peng et al., 2023; Pesenti Rossi et al., 2024). Further, calves across both treatment groups averaged 22 lying bouts per day with an average bout duration of 53.8 minutes, both of which align with results from a study by Bonk et al. (2016) looking at the effect of colostrum feeding methods on lying behavior. Though there was no effect of treatment, there was an effect of age on lying behavior, where calves spent a lower proportion of their time lying down, had fewer daily lying bouts, and had a longer average lying bout duration at 7 weeks of age compared to weeks 1-3 of age. This agrees with numerous other lying behavior studies showing that proportion of time spent lying decreases with age during the preweaned period (Borderas et al., 2009; Peng et al., 2023; Riley et al., 2023; Pesenti Rossi et al., 2024). One limitation of the current study was that calves ranged in age from 2 days old to 6 days old during the first day of lying behavior collection, and lying behavior in this age range may not have been homogenous. Previous research has shown increased lying behavior during and after transport in calves aged 2–5 days compared to those 6 days or older (Bajus et al., 2023), with total lying time decreasing progressively between 2, 3, and 5 days of age (Jongman and Butler, 2014; Bonk et al., 2016). While the current study did not analyze or account for potential variation in lying behavior between calves of different ages during the first week of collection, which could have led to slightly greater proportions of time spent lying during the first week of collection, age ranges and average calf age was even across treatment groups, so this likely did not affect analysis of treatment effects.

Another limitation of this study that may have been a reason for not seeing treatment differences could be the small sample size of 13 calves per treatment. However, this sample size was calculated based on results from a previous behavior study looking at the effect of nutritional interventions on lying behavior (Todd et al., 2018). Additionally, the sample size per treatment group among previous behavior studies analyzing the effects of nutritional interventions on preweaned calves, such as increased milk total solids or increased acidification of milk, ranges from 4-24 calves, with the average being 12 calves per treatment group (Phillips, 2004; Todd et al., 2018; Rufino et al., 2019; Alimirzaei et al., 2020; Shiasi Sardoabi et al., 2021). The majority of these studies did not see a treatment difference in their sample population. For example, a study conducted by Shiasi Sardoabi et al. (2021) looked at the effect of greater percent total solids fed to calves, which was true of the COL treatment compared to the CON treatment in the current study, on the lying behavior of four treatment groups containing 12 calves each; The authors found no significant differences in any of the measured behaviors, which is similar to the current findings. However, another study by Rufino et al. (2019) that also analyzed the effect of increasing total solids concentrations in milk across four treatment groups, each with 15 calves, did report seeing treatment differences, such that calves receiving either of the two highest percentages of total solids (18.2% and 20.4%) spent more time lying than those receiving the two lowest percentages of total solids (13.5% and 16.1% total solids; Rufino et al., 2019). Since both previous studies, along with the current study, had similar sample sizes per treatment group, one reason for Rufino et al. (2019) seeing a treatment difference when others did not could be the greater overall level of total solids tested; Rufino et al. (2019) reported a treatment difference when increasing total solids to 18.2% and 20.4%, whereas the total solids percentage in the milk provided during the current study averaged 15-17% and the total solids percentages in the milk provided during the study by Shiasi Sardoabi et al. (2021) was preset at either 12% or 17%, pointing to a difference in research interests and methodologies rather than sample size calculations. Further, when expanding the review of literature to include other research studies looking at how lying behavior may be impacted by varied milk and colostrum feeding methods, frequencies, and/or volumes, a similar low sample size and rarity of finding significance between treatment groups appears (Bonk et al., 2016; Dong et al., 2017; Jensen et al., 2020). However, the current study did not see anecdotal differences in treatment means, indicating there would likely not be a treatment difference even with a larger sample size.

The results of the present study are most applicable to herds with high incidence of diarrhea and moderate incidence of respiratory issues among their preweaned calf population. Health was not the primary objective of the present study. However, discussing health is important to understand external validity. Overall, the current study population had very little variation in incidence of disease, where nearly all calves (25/26; 96%) had at least one diarrhea bout during the study period, very few calves (3/26; 11.5%) presented with respiratory issues, and none presented with joint or navel infections. Given that nearly all calves were affected, morbidities were approximately equal between the two treatment groups. Recent observational studies surveying morbidities of diarrhea and bovine respiratory disease (BRD) in Ontario dairy farms indicate individual calf-level prevalences of 33% for diarrhea and 6.7% for BRD, as well as median herd-level prevalences of 10.2% for diarrhea and 21.6% for BRD (Windeyer et al., 2014b; Umaña Sedó et al., 2025). Additionally, in a 2014 study conducted by the United States Department of Agriculture, calf caretakers collectively reported over 50% of calves having digestive issues and 28% having respiratory issues, with an additional 5.4% showing both digestive and respiratory issues (USDA NAHMS, 2022). Thus, the 96% herd-level morbidity for diarrhea present in the current study was greater than observed averages on Ontario dairy farms, as well as greater compared to the producer-reported averages in the United States. Additionally, the 11.5% herd-level morbidity for respiratory issues in the current study results was high compared to averages observed on Ontario dairy farms but low compared to the producer-reported averages in the United States. These differences in disease morbidity may be attributed to differences in management, breed type, or sex, as previous study results all represent morbidities for conventionally raised replacement heifers, whereas the current results only apply to non-replacement animals that included both bulls and heifers raised in a non-conventional setting. For example, male dairy calves have been reported to have greater mortality rates than females (Cuttance and Laven, 2019). However, dairy calves born to a beef-type sire have recently been reported to have a lower incidence of diarrhea than those born to dairy-type sires, which is in opposition with the high rates of diarrhea seen in the current study containing primarily beef-sired calves (Kovacs, 2025). Lastly, the calves in the current study were allotted more pen space than is common for many dairy calf ranches in the Western United States, which has been reported to have an association with improved health of these animals (Calvo-Lorenzo et al., 2016). An additional reason for differences in health between the current study and previous research could be the increased interaction with a large number of students, faculty, and staff members, as these calves were also used for hands-on teaching activities within the university. Each calf was handled by multiple different people each week via university-sanctioned teaching activities, which could have led to inconsistent handling causing physiological stress and increased pathogen exposure and/or tracking throughout the facility (Jurkovich et al., 2024; Barnhardt and Raabis, 2025). Overall, the health of this population did not align with current research in terms of level of impaction by ECF programs or in terms of herd- and individual calf-level averages, which could have been due to differences in characteristics of the animals included in the study population or the differences in management strategies between studies. As health has been known to impact lying behavior, the results of this study are most relevant to farms with similar morbidities to those seen in the current study.

In terms of nutrition, results from the present study are most applicable to farms feeding a moderate plane of nutrition, such that calves are receiving a restricted volume of milk replacer with at least 22% fat. Growth was not the primary outcome of the study. However, the growth rates of the calves in the current study were consistent with past research and current recommendations. The average daily gain of the calves included in the study population was approximately 0.79 kg/day, which falls squarely within the recommended range of 0.71-0.91 kg/day proposed by Hyde et al. (2021) and exceeds with the average daily gain value of 0.74 kg/day that was reported by a national survey of dairy calves done in 2014 (USDA NAHMS, 2022; Hyde et al., 2021). Additionally, the feed efficiency of the calves in the current study were 28% (0.28 kg of gain per 1 kg of protein consumed in milk) and 22% (0.22 kg of gain per 1 kg of protein consumed in milk) for CON and COL calves, respectively, both of which fall above herd-average feed efficiency of 20% reported in the same 2014 national survey (USDA NAHMS, 2022). Past ECF studies have indicated a positive impact on overall weight gain and feed efficiency (Berge et al., 2009; McCarthy et al., 2024), which disagree with current findings. However, once again the current study was limited in calf-level variation and variation between treatment groups due to smaller sample sizes in the current study compared to past studies with health and/or growth as their primary outcome variable rather than behavior. In short, calf-level growth and feed efficiencies, though not impacted by the ECF program, were consistent with previous studies in terms of herd-level averages.

In conclusion, there was no difference in preweaned lying behavior between non-replacement calves receiving supplemental colostrum in their diet and those receiving only milk replacer during the first 14 days of life. Future studies in this topic area should continue to look at the effects of ECF on additional behaviors, and with a larger sample size, as well as health and growth measures, in a variety of industry settings. Research done with varied structures of ECF programs, such as varying volume, concentration, and timing of extended colostrum feedings, should also be explored. Conducting more ECF studies overall to create a larger database of information would be helpful in further exploration of the impact of ECF on dairy calves' health, productivity, and overall welfare.

2.5 Tables and Figures:

Table 2.1. *Least squares means table outputs for effects of treatment (CON/COL), breed type (B×D/H), and sex (Heifer/Bull) on lying behavior.*

Variable	Treatment		Breed		Sex		*P*-Value		
	CON	COL	B×D	Holstein	Heifer	Bull	TRT	Breed	Sex
Lying Time (%)	78.8 ±1.5	79.5 ±1.5	78.9 ±0.7	79.5 ±2.5	79.0 ±1.5	79.3 ±1.5	0.63	0.82	0.83
Lying Bouts (n)	23.8 ± 1.1	23.7 ± 1.1	21.4 ± 0.5	26.3 ± 2.1	24.5 ± 1.1	23.0 ± 1.1	0.96	0.01	0.17
Lying Bout Duration (min)	48.5 ± 3.3	49.6 ± 3.3	54.7 ± 1.6	43.5 ±5.5	47.2 ± 3.2	50.9 ± 3.3	0.71	0.05	0.23

Table 2.2. *Least squares means table outputs for differences in lying behavior across experimental dates, averaging over both treatment groups. All model analyses indicated a significant difference in lying behavior across experimental dates (P < 0.001).*

Experimental Day	Lying Time (%)	Lying Bouts (n)	Lying Bout Duration (min)
1	85.1 ± 1.1	28.5 ± 1.7	43.6 ± 3.5
2	83.8 ± 1.2	26.2 ± 1.6	47.2 ± 3.5
3	83.0 ± 1.2	24.1 ± 1.5	50.7 ± 3.5
7	80.2 ± 1.4	23.3 ± 1.4	50.2 ± 3.4
8	78.4 ± 1.5	23.6 ± 1.4	47.6 ± 3.4
9	76.7 ± 1.5	25.0 ± 1.5	44.0 ± 3.4
13	78.0 ± 1.5	26.4 ± 1.5	41.9 ± 3.4
14	79.1 ± 1.4	27.5 ± 1.6	42.0 ± 3.4
15	79.2 ± 1.4	24.1 ± 1.4	47.0 ± 3.4
16	80.2 ± 1.4	24.5 ± 1.4	51.5 ± 3.4
48	74.2 ± 1.6	19.2 ± 1.2	58.9 ± 3.4
49	74.0 ± 1.6	20.1 ± 1.2	53.7 ± 3.4
50	74.6 ± 1.6	18.7 ± 1.2	59.5 ± 3.4

3. FACTORS ASSOCIATED WITH STUDENT SUCCESS IN AN INTRODUCTORY LEVEL ANIMAL SCIENCE COURSE

3.1 Introduction

In higher education institutions across the United States, science, technology, engineering, and mathematics (STEM) disciplines are experiencing enrollment rates that are greater than ever with shifts towards increased racial and gender diversity (Ramirez and Kwak, 2015; Jacome, 2021). An increase in non-traditional student enrollment has been noted as well, which includes any students enrolled over the age of 24, students working full-time, students only enrolled part-time, students with dependents other than their spouse, and GED recipients (National Center for Education Statistics, n.d.). Animal science is one such STEM discipline that is experiencing these trends in higher education, with over 8,000 Animal Science degrees awarded nationwide in 2022, compared to just 6,000 in 2012, as well as a shift from a primarily white male dominated demographic to a primarily female dominated demographic with a more diverse group of racial and ethnic identities represented in the last decade (Data USA, 2023). Additionally, enrollment in animal science programs is most popular in institutions with affiliated veterinary schools and institutions that serve as a land-grant university. Of the top ten institutions with the greatest proportion of degrees awarded in animal sciences, 90% have an affiliated AVMA-accredited veterinary school and 80% serve as their state's land-grant institution (Data USA, 2023; AVMA, 2025). One potential reason for preference for enrollment in these institutions could be the high proportion of students that enter the discipline to pursue a career in veterinary medicine or to enter production livestock industries, both of which are supported by and often work with land-grant universities.

Colorado State University (CSU), which is both affiliated with an accredited veterinary school and serves as Colorado's land-grant university, has experienced a similar rise in animal science degree enrollment and expansion of racial-, ethnic-, and gender-based diversity within the degree program. The university reports a nearly 20% increase in total animal science undergraduate enrollment and a 60% increase in racially minoritized student enrollment in the past decade (Colorado State University, 2025a). Further, 88% of students enrolled in the animal sciences degree program at CSU identify as female, making it a female-dominated major, unlike many other STEM disciplines (Colorado State University, 2025a). However, CSU is experiencing significantly lower 4- and 6-year graduation rates for animal science students when compared to peer institutions offering the same major. For example, the 4- and 6-year graduation rates at CSU are 51.9% and 66.7% respectively, which is much lower than the 62% 4-year graduation rate for the entire State University System of Florida, the 84.2% 6-year graduation rate of Texas A&M, and the 88% 6-year graduation rate of the University of Illinois Urbana-Champaign (Page, 2024; Texas A&M University, 2024; Colorado State University, 2025a; University of Illinois Urbana Champagne, n.d.). While these universities have been known to have lower admission rates compared to CSU due to more selective admissions criteria, University of Illinois Urbana-Champaign, 2025; U.S. News & World Report, 2025), which may impact graduation rates, they are all quite similar to CSU in that they are large, land-grant universities with heavy focuses on agricultural science disciplines. Moreover, when comparing graduation rates across departments university-wide, the Department of Animal Sciences has 4- and 6-year graduation rates of 40.1% and 58.1% respectively, which are lower than those of more than half of the other departments at CSU, as well as lower than the 51.9% 4-year and 66.7% 6-year average graduation rates for all STEM departments combined at CSU (Colorado State University, 2025a). Graduation rates are one of several metrics used to measure student success, alongside outcomes such as skills, grade point average, self-efficacy, holistic growth, self-directed learning, and post-graduation career status. General student success indicators are difficult to track across an entire university. Therefore, graduation rates serve as a simple but limited system-wide indicator. Further, low graduation rates often signal broader challenges with student success. Rising enrollment and increased diversity at CSU, coupled with persistently low graduation rates, raise concerns about whether existing support structures are truly meeting student needs. These shifting demographics underscore the importance of ensuring support systems are both effective and equitable enough for students of all identities and backgrounds to succeed.

Improving academic outcomes among students requires an understanding of how students' academic behaviors, activities, and attitudes contribute to their academic performance. Research shows that involvement in campus clubs, organizations, and educationally purposeful activities improves grades, retention, and application of learning (Kuh et al., 2008; Hawkins, 2015). Additionally, students engaged in undergraduate research achieve greater GPAs and graduation rates compared to those that are not (Schneider et al., 2021). Such involvement also enhances belonging and authenticity, which benefits performance, motivation, and perceived support (Freeman et al., 2007; Cwik and Singh, 2022; Verbree et al., 2025). Involvement also fosters meaningful connections with faculty and staff, which increases persistence within a major and an institution (Hawkins, 2015; Xu, 2018). Additionally, students are more likely to utilize existing academic and social support structures when they are promoted by trusted peers or faculty members, further reinforcing the value of creating meaningful connections with faculty and other students alike (Kearns et al., 2015; Qayyum, 2018; Hagler et al., 2023). Beyond involvement, effective learning strategies such as improved notetaking, studying methods and hands-on, experiential, and collaborative learning approaches are linked to better test scores, greater interest, and stronger self-efficacy (Mendezabal, 2013; Sebesta and Speth, 2017; Bradberry and De Maio, 2018; Burch et al., 2019; Oje et al., 2021). Studies have also linked attendance patterns to student success outcomes (Al Hazaa et al., 2021), though this relationship may be influenced by other factors like in-class participation and demographic or background factors (Halpern, 2007; Kim et al., 2020). Lastly, numerous studies have examined the role that demographic factors and background characteristics play in student success, and from these, it has been determined that race, gender, socioeconomic background, and first-generation college status can create hidden obstacles to academic success (Crisp et al., 2009; Whalen and Shelley, 2010; Çiftçi and Cin, 2017; Zuo et al., 2017). Overall, involvement, strong academic and social connections, effective learning strategies, consistent attendance, and numerous demographic and background factors all play major roles in student success in higher education. These factors could be used to inform current and future student support systems and topics to improve university student success on a more holistic level.

To develop effective support systems more tailored for animal science students, however, it is essential to understand which factors specifically influence success within the discipline. Limited studies have highlighted benefits of hands-on learning and critical thinking in animal science courses (Ferree et al., 2022; Ragland et al., 2023; Scott et al., 2023), as well as self-motivation (Lavoie, 2019), positive attendance patterns (McMillan et al., 2009), and participation in learning communities (Zinn et al., 2015). Most other research has focused on demographic and background characteristics (Hale and Rosenkrans, 2004; Gwazdauskas et al., 2014; White et al., 2015; Vinyard et al., 2022), yet even these findings conflict regarding their impact on student success. For example, the study by Gwazdauskas et al. (2014) found gender to have a significant effect on final course grade in an Anima Anatomy and Physiology course whereas the study by Vineyard et al. (2022) found no effect of gender on academic performance. More work is therefore needed to identify academic behaviors, activities, and attitudes associated with success in animal sciences, as well as to clarify how demographic and background factors influence outcomes. The objectives of this study were to (1) determine which student behaviors (e.g., involvement, attendance patterns, notetaking strategies, and study practices strategies) were associated with final grades in an introductory animal science course, and (2) to identify which demographic and background characteristics of animal science students were associated with final grades in the same course.

3.2 Methods

Data collection for this retrospective observational study took place at Colorado State University (CSU) in December 2021, 2022, and 2023 during the final laboratory period of the course titled ANEQ 101: Food Animal Science. The CSU Institutional Review Board (5789) approved the research plan prior to data cleaning and analysis.

3.2.1 ANEQ 101 Course Overview

In the Department of Animal Sciences at CSU, the "Introduction to Food Animal Science" (ANEQ 101) course is required for all students within the animal science major and is often taken during their first semester. It also serves as a common elective course for other students in the College of Agricultural Sciences, as well as for those who are interested in veterinary medicine. The ANEQ 101 course objectives are to (1) Explore the development, organization, trends and management of all sectors of the livestock industry and (2) Apply scientific principles to the production of food and fiber. The course includes 3, 50-minute lectures and a required 110-minute lab per week. During the lecture portion, students are provided with material on all sectors of the livestock industry, as well as basic livestock principles such as anatomy, physiology, nutrition, handling and husbandry, and veterinary care. Students also receive guest lectures from faculty members in the department and monthly club/activity announcements to keep them informed about what is happening within the department and ways to get involved. One highlight of the course is the opportunity for students to work hands-on with dairy calves for the first 5 weeks of the semester. In those weeks, groups of 3-5 students are assigned to a week-old calf and tasked with learning how to feed, handle, weigh, and provide basic husbandry for their assigned calf. All students can volunteer as often as they wish to help during the twice-daily feedings and health checks for these calves. Volunteering to help feed and care for these calves is not required, nor is it attached to their final grade in any way but can provide an opportunity for further hands-on and experiential learning outside of the course setting, as well as an opportunity for extracurricular involvement and more meaningful connections with faculty and teaching assistants. The course was chosen for analysis because it enrolls many first-semester students, a critical period for shaping long-term academic success.

3.2.2 Study Population and Recruitment

The ANEQ 101 instructor developed a survey (Appendix H) to identify ways to support student success and improve the course's curriculum and pedagogy in future semesters. The anonymous survey was administered during the final laboratory period of the course. The survey was not mandatory or associated with a student's final grade. However, teaching assistants strongly encouraged students to complete the survey to help improve the course in future semesters. Only those that attended the final laboratory period were asked to complete the survey. No identifiers were collected during this process.

3.2.3 Survey Development and Content

This survey included five sections: Course Overview, Course Performance, Weekly Labs, Challenges, and Demographics. In sections 1 and 3, participants were asked multiple choice questions regarding overall perceptions of course material and its importance and relevancy, for both lecture (section 1) and laboratory (section 3) portions of the course. In section 2, participants were asked to describe current grades, study habits, attendance patterns, and involvement in extracurricular activities related to animal sciences in a series of multiple choice and free-response questions. In section 4, participants were asked Likert-scale questions with possible responses of "Strongly Agree," "Agree," "Disagree," or "Strongly Disagree" regarding current challenges they faced in the course throughout the semester. Finally, section 5 allowed respondents to describe their demographic identities via multiple choice and free-response questions. Not all survey questions were related to the current study objectives, so only 57.8% (n=26/45) of questions were included in the final analysis. The questions that were used in the analysis, as well as the general categories they each fall under, are included in supplemental material (Appendix C).

3.2.4 Statistical Analysis

Survey responses were entered into Excel (Microsoft Corp., Redmond, WA) and stored for compilation and initial screening. All surveys were at least 70% complete, so all were included in final analysis. Data were cleaned and analyzed using Excel and SAS software (SAS Institute., Cary, NC). The outcome of interest was students' self-reported grade in ANEQ 101 at the time of the survey. Though the survey was distributed during the final week of the semester, the students' grades did not include the results of their final examinations or last homework assignment at the time responses were collected. Final course grade was initially analyzed as a categorical variable (A, B, C, D, or F) and later collapsed into a dichotomous categorical variable: "pass" (grades A, B, and C) and "fail" (grades D and F). Predictor variables included both categorical and dichotomous measures: lecture and laboratory attendance, high school GPA, and gender were categorical, while extracurricular involvement, perceptions of note-taking and study habits, study difficulties, desire to improve study or note-taking habits, and demographic factors (first-generation status, number of course enrollments, transfer status, and race) were dichotomous (Table 3.1). Some variables were originally categorical as Likert-scale data (strongly agree/agree/disagree/strongly disagree) but were later collapsed to be dichotomous (agree/disagree; Table 3.1).

Preliminary bivariate analyses (PROC FREQ) assessed associations between predictor variables (student involvement, learning strategies, perceived adequacy of learning strategies, attendance, and key demographic factors) and the outcome of interest (final course grade); Predictors with a P-value less than 0.20 were considered to have a conservative association with the outcome of interest and were thus retained for multivariable analyses (Dohoo et al., 2009). Chi-squared and P-values are reported for each bivariate analysis. To assess whether demographic factors acted as potential confounders in the relationship between other predictors and final grade, separate bivariate analyses were run for all combinations of demographic and predictor variables that showed conservative associations with the outcome ($P < 0.20$), including associations among demographic factors themselves. Demographic factors that were associated with another predictor ($P < 0.05$) were included as potential confounders in later multivariate analyses.

Nine multivariable models were constructed, one for each of the following primary predictors: overall involvement (all involvement-related predictors collapsed into one variable, yes/no), experienced difficulty while studying, perceived need to improve study skills, perceived inadequacy in time spent studying, perceived personal inadequacy of notetaking strategies, perceived need to improve notetaking strategies, lecture attendance, laboratory attendance, and demographic/background characteristics. Multivariable logistic regression (PROC GLIMMIX) in SAS (Version 9.4M8; SAS Institute Inc., Cary, NC), were used to assess if the predictors of interest were associated with the outcome, while controlling for potential confounders. All full multivariable models included high school GPA (HSGPA), race, first-generation (FG) student status, and times enrolled in the course, with the addition of the respective primary predictors (Table 3.2). Interactions were checked between the primary predictor of interest and each demographic factor included as a potential confounder in the model. Backwards stepwise removal was performed until only statistically significant variables and interactions ($P < 0.05$) remained in the models. The final models for the effects of involvement, attendance, and notetaking/studying habits on final course grade included the respective primary predictors for each model, HSGPA, race, and times enrolled in the course, while the final model for the effects of demographic factors on final course grade included race, times enrolled in the course, and the interaction between HSGPA and FG student status (Table 3.2). For each model, estimates, standard errors, and individual P-values were provided by the PROC GLIMMIX command against a referent level of each variable. Predictive probabilities and associated standard errors were also calculated for all levels of each variable included in the final models using the ilink command from the LSMEANS function of PROC GLIMMIX. These probabilities were calculated as the probability of a student earning a failing grade.

3.3 Results

3.3.1 Respondent demographics

Over the course of three consecutive fall semesters, 556 total survey responses were received (n=174 in 2021, n=184 in 2022, and n=198 in 2023). Across all three semesters, 85.6%

(n=474) of respondents indicated having a passing grade in the course (A, B, or C) and 14.4% (n=80) indicated having a failing grade (D or F). The majority of respondents identified as female (77.0%; n=428) and as white (64.6%; n=359). Most of the respondents were in their first year of college (74.5%; n=414) and nearly all were taking ANEQ 101 for the first time (96.2%). Most respondents were Animal Science majors (85.1%; n=473) with most respondents (66.5%; n=370) indicating an interest in attending veterinary school following graduation. Nearly a third (30.8%; n=171) of respondents identified as a first-generation student in their family and 12.9% (n=72) indicated being a transfer student. Across all three semesters, 7.4% (n=41) of respondents indicated being enrolled in the University Honors Program and 34.0% (n=189) indicated having a full- or part-time job while attending classes. Lastly, over half of the respondents (58.5%; n=325) indicated originating from a state other than Colorado. Respondent demographics are described further in Table 3.3.

3.3.2 Factors Associated with Final Grade: Bivariate Analysis Results

Involvement in the department, perceived adequacy of notetaking and study habits, and attendance patterns while enrolled in ANEQ 101 were all significantly associated with a student's final course grade. More specifically, in regard to involvement within the department, connecting with faculty, being involved in department research, volunteering to feed dairy calves used for labs, and joining a club all were associated with a student's final course grade ($P < 0.02$); Table 3.4). However, in the current study, only 23.0% (n=128) of respondents indicated having connected one-on-one with a faculty member while being enrolled in the class, 6.12% (n=34) of respondents indicated being involved in department research, 37.1% (n=206) indicated volunteering to feed calves, and 40.6% (n=226) indicated having joined a club. Further, when asked to select some reasons they might not have done as well in the course as they had hoped, 14.0% (n=78) of respondents indicated the quality of their notetaking was inadequate, 41.5% (n=231) indicated they did not study as much as they should have, and 39.4% (n=219) indicated it was difficult for them to study and/or prepare for quizzes and exams. When the effects of learning strategies such as notetaking and study habits on final grade were analyzed in a bivariate analysis, an association was seen between final course grade and perceived adequacy of notetaking ability ($X^2 = 14.84$; $P < 0.0001$; Table 3.4), perceived adequacy of the amount of time spent studying ($X^2 = 8.65$; P = 0.003; Table 3.4), perceived adequacy of study habits and skills ($X^2 = 9.76$; $P = 0.002$; Table 3.4), and perceived difficulty of studying/preparing for quizzes and exams ($X^2 = 44.20$; $P < 0.0001$; Table 3.4). However, there was no significant relationship between the act of taking notes in class (yes/no), regardless of the style of notetaking, and final grade ($X^2 = 0.19$; $P = 0.66$). Similarly, there was no significant relationship between the amount of time a student spent studying and their final grade ($X^2 = 65.74$; $P = 0.62$; Table 3.4).

Additionally, across the three semesters of data collection, 20.8% (n=116) of student respondents indicated attending all lectures, 37.6% (n=209) indicated attending all but one or two lectures, 35.3% (n=196) indicated all but 3-10 lectures, and 5.9% (n=33) indicated missing more than 10 lectures. Similarly, 42.3% (n=235) of student respondents indicated attending all labs, 53.2% (n=296) indicated attending all but one or two labs, and 4.3% (n=24) indicated missing three or more labs. From initial bivariate analyses, an association was seen between a student's final grade and their lecture attendance ($X^2 = 26.1305$; $P < 0.0001$; Table 3.4), as well as between final grade and their laboratory period attendance ($X^2 = 26.8053$; $P < 0.0001$; Table 3.4).

Lastly, numerous demographic and background factors were tested via bivariate analysis to determine which ones were associated with final course grade. From this, it was determined that a student's HSGPA ($X^2 = 13.1950$; $P < 0.0001$; Table 3.4), the student's race ($X^2 = 35.0766$; $P <$

0.0001; Table 3.4), times enrolled in the course ($X^2 = 32.2150$; $P < 0.0001$; Table 3.4), and whether a student was part of the first generation in their family to attend higher education (FG; $X^2 = 10.3071$; $P = 0.0013$; Table 3.4) were all significantly associated with that student's final course grade. Other demographic factors such as gender and transfer student status were not significantly associated with a student's final course grade ($X^2 = 9.519$, $P = 0.1032$; $X^2 = 3.0447$; $P = 0.079$, respectively; Table 3.4). Bivariate analysis was also used to determine potential covariance between demographic factors and all other primary predictors, including other demographic factors. There were many significant associations between predictors and demographic factors, suggesting the presence of covariance; The results of this analysis are provided in supplemental material (Appendix G).

3.3.3 Factors Associated with Final Grade: Multivariate Analysis Results

Based on results of the bivariate analysis, multivariable models were created for each of the following predictors: overall involvement (Model 1), experienced difficulty while studying (Model 2), perceived need to improve study skills (Model 3), perceived inadequacy in time spent studying (Model 4), perceived personal inadequacy of notetaking strategies (Model 5), perceived need to improve notetaking strategies (Model 6), lecture attendance (Model 7), laboratory attendance (Model 8), and demographic/background characteristics (Model 9) (Table 3.2).

When analyzing the effects of extracurricular involvement on final grade in multivariate analysis, responses for each of the involvement activities asked in the survey were combined to create a new binary variable for overall involvement, which indicated involvement in at least one activity (yes/no). Model 1 was used to analyze the effects of this new involvement variable on final grade, which showed that students who were involved in at least one extracurricular activity within the department had a 27.4% predicted probability of failing ANEQ 101, which is significantly lower than the 45.2% probability for those that were not involved in any way, when controlling for high school GPA (HSGPA), race, and number of times enrolled in the course. (P = 0.0055; Table 3.5).

Models 2-6 were used to analyze the effects of studying and notetaking strategies on final grade when controlling for potential demographic variable confounders. For Model 2, which looked at the effect of a student experiencing difficulty when studying on final grade, it was determined that students that reported difficulty studying had a 45.5% probability of failing ANEQ 101 compared to the 16.7% probability for those who did not, when controlling for HSGPA, race, and times enrolled in the course ($P < 0.0001$; Table 3.6). However, Models 3 and 4 analyzed the effects of perceived needs to improve study skills and perceived inadequacies in time spent studying and found no effect of those predictors on final grade, when controlling for potential confounders ($P = 0.9761$ and $P = 0.1369$, respectively). When looking at the association between perceived personal inadequacy in notetaking strategies (Model 5), it was noted that students who indicated having this perceived inadequacy of their notetaking strategies were associated with a higher probability of failing compared to those that did not (45.2% and 26.5%, respectively; P = 0.0128; Table 3.7), when controlling for HSGPA, race, and times enrolled in the course. Lastly, estimates and predicted probabilities from Model 6 show that students who reported a need to improve their notetaking strategies had a 35.6% probability of earning a failing grade, which is significantly higher than the 10.4% probability of failing for those that did not feel the need to improve their notetaking strategies ($P = 0.0006$). Full outputs of this multivariate model are available in supplemental material (Appendix D). In short, results from Models 2-6 indicate that students that felt inadequate in their learning strategies had a higher probability of failing compared to those that did not.

The effects of attendance, both for lecture and laboratory periods, when accounting for potential confounders were analyzed using Models 7 and 8, respectively; The full outputs of these multivariate models are available in supplemental material (Appendix E-F). Results of Model 7 show that when accounting for HSGPA, race, and times enrolled in the course, students that indicated attending lectures 90% of the time or less (missing 3+ lectures) had a significantly higher probability of earning a failing grade than those that indicated attending 100% or almost 100% of the time (missing 0-2 lectures) (80-90%: $P = 0.0099$; ≤ 70%: $P = 0.0045$). However, the students that indicated attending lectures almost 100% of the time did not have a different likelihood of failing compared to those that indicated attending 100% of lectures ($P = 0.1854$). It was determined that when controlling for HSGPA, race, and times enrolled, students attending 100% of lectures had a predicted 14.6% probability of failing and those attending almost 100% of lectures had a predicted 24.2% probability of failing, which is lower than the predicted 35.5% and 48.3% probabilities of failing for those attending 80-90% and 70% or less of lectures, respectively. A nearly identical pattern was observed when analyzing the association between laboratory period attendance and a student's final grade in the course, where those that attended ≤ 70% of laboratory periods (missing 4+ laboratory periods) had a higher probability of failing than those that attended all or nearly all of the laboratory periods ($P = 0.0076$). However, there was no difference in probability of failing between those that attended 100% of the laboratory periods and those that attended 80-90% of the laboratory periods ($P = 0.0950$). Students that attended the laboratory periods 100% of the time had a predicted 23.24% probability of failing and students that attended the laboratory periods 80-90% of the time had a predicted 33.4% probability of failing, which are both much lower than the 57.5% predicted probability of failing for those that only attended the laboratory periods ≤ 70% of the time, among students with the same HSGPA, race, and number of times enrolled in the course. Therefore, students with poorer attendance patterns in the three-times weekly lectures and/or in the weekly laboratory periods had a greater likelihood of failing compared to those that attended more regularly, among those with similar demographic identities.

Lastly, all demographic factors determined to be associated with final grade in a bivariate analysis were tested together in one multivariable model (Model 9) to determine the effects of each factor on students' final course grades in ANEQ 101, when accounting for the effects of the other demographic factors. There was a significant relationship between final grade and a student's HSGPA, number of times enrolled, and their race, when accounting for the effects of the other two ($P < 0.001$; Table 3.8). There was also a significant interaction seen between first-generation (FG) status and HSGPA ($P = 0.0397$), so the final model output for Model 9 includes the main effects for race and times enrolled, as well as the interaction effect for HSGPA*FG status (Table 3.2). The results of this model indicate that the effect of FG status on final grade differs by HSGPA range, where among only students with a HSGPA of 4.00 or higher, FG students had a much higher predicted probability of failing than non-FG students, but, the same was not true for students with HSGPA 3.00-3.99 or for those with HSGPA less than a 3.00 (Table 3.8). Instead, minimal difference was seen in the likelihood of failing between FG and non-FG students in the 3.00-3.99 HSGPA range (31.1% and 31.5%, respectively) and for students in the less than 3.00 HSGPA range, FG students had a lower predicted probability of failing than non-FG students (39.8% and 62.9%, respectively; Table 3.8). The results of this multivariate model also indicate that students of any minoritized race have a 43.8% predicted probability of failing ANEQ 101, which is more than twice that of white students (18.0%), when controlling for HSGPA, FG status, and number of times enrolled (Table 3.8). Lastly, Model 9 results show that students that are retaking ANEQ 101 have an approximately three times higher predicted probability of failing ANEQ 101 than those taking it for the first time (47.6% and 15.8%, respectively), when controlling for HSGPA, FG status, and race (Table 3.8). Overall, when controlling for the other demographic factors, FG students with a high HSGPA, non-FG students with a low HSGPA, racially minoritized students, and students that are retaking the course are more likely to fail ANEQ 101 than their respective counterparts.

3.4 Discussion

The College of Agricultural Sciences at Colorado State University (CSU) is currently experiencing enrollment numbers that are higher than ever, especially within the Department of Animal Sciences, yet 4-year graduation rates are consistently in the middle to high 40% range. This shows that over half of enrolled students may not be receiving adequate support to succeed academically. While these numbers are specific to CSU, the lack of effective student support strategies is an issue seen at many other institutions, as reflected by low retention and graduation rates (U.S. Department of Education, n.d.). This issue is further exacerbated by the shifting demographics and growing diversity on campuses, creating more opportunities for hidden obstacles to exist for students of all identities. Past studies have shown support strategies that are effective in improving student success in other STEM disciplines (Kuh et al., 2008; Credé et al., 2010; Mendezabal, 2013; Hawkins, 2015; Richardson and Latz, 2016; Sebesta and Speth, Schneider et al., 2021), but little is known about effective strategies for animal science students specifically. By more adequately supporting students, especially during their first semester, they are more likely to remain at the university and within the major, which can lead to increased success later in their educational journeys as well as in their professional careers following graduation. Therefore, this study aimed to assist in these efforts by identifying factors associated with student success in the introductory animal science course at CSU, as well as demographic factors that could be impacting how current support structures influence the success of animal science students.

3.4.1 Demographics

The current survey was distributed to students enrolled in the introductory animal science course at CSU during Fall 2021, 2022, and 2023, the majority of which indicated being in their first year of a bachelor's degree program in Animal Sciences. Introductory courses are typically taken by first-year students in a degree program or related fields, as they often serve as prerequisites for future required courses (Peffer, 2011; Lavoie, 2019; Colorado State University, n.d.). A majority of the respondents identified as white and as female, which aligns with both animal science specific demographics and university-wide demographics for CSU (Colorado State University, 2022; Institutional Research Planning and Effectiveness, Colorado State University, 2024). This also aligns with similar studies of animal science undergraduates conducted at other agricultural colleges and universities (Bobeck et al., 2014; White et al., 2015; Lavoie, 2019; Carlson et al., 2024)). A significant number of respondents were first-generation (FG) college students (31%), though they did not represent the majority. In the last decade, roughly a third of animal sciences students and nearly a quarter of all students at CSU identified as FG students (Institutional Research Planning and Effectiveness, Colorado State University, 2024). According to a national report by the Center for First-Generation Student Success (2023), 54% of all undergraduates and 48% of undergraduates at public 4-year universities identified as FG students as of 2020, with FG being defined as having parents who did not receive at least a bachelor's degree (RTI International, 2023). Therefore, the current study demographics align well with what is seen nationwide. The current study population also has a significant proportion of students that are transfer students, coming to CSU either from a different 2-year or 4-year university. According to the National Student Clearinghouse (2024), roughly 13.2% of all undergraduate students at 4-year universities are transfer students, which aligns with the 12.9% of students that identified as transfer students in the current study (National Student Clearinghouse, 2024). Lastly, a larger percentage of respondents in the current study are not residents of Colorado (59%) compared to the 40% non-resident average across all degree programs at CSU. This is likely in part due to the current study's respondent pool being primarily composed of animal science students, most of which indicated an interest in veterinary medicine following graduation. In 2023, the Doctor of Veterinary Medicine program at CSU was ranked #2 in the nation by the U.S. News and World Report (US News, 2025), which brings in students from across the country that are interested in veterinary medicine.

3.4.2 Academic Behaviors Associated with Student Success

According to data from the current survey, students that were involved in extracurricular activities within the department had lower probability of earning a failing grade in the Introductory Animal Science course at CSU. The specific types of included departmental involvement in research, extracurricular communication with departmental faculty, and joining a club on campus. The proportion of students in the current survey that were involved in research (7%) is smaller than the university wide average of 15% (Colorado State University, 2025b), but this is to be expected as only 6% of first-year students participated in research at CSU, compared to 30% by their fourth year (Dominguez and Novak, 2019), and the large majority of current study respondents were in their first year of their degree program. Similarly, only 23% of survey respondents reported connecting with faculty, which is slightly lower than data from the National Survey of Student Engagement (NSSE), where 30–46% of CSU students and 21–39% of students at other large land-grant institutions reported at least one interaction with faculty outside class

(Dominguez and Novak, 2019). This difference is exacerbated further when considering that the NSSE split the proportion of students who met with faculty outside of class time by the topic they discussed with the faculty members (ex. met with faculty to discuss a quiz, met with faculty to discuss future plans, etc.), so the overall number of students that had any type of one-on-one connection with faculty could be even greater than what was reported. The proportion of students that seek out intentional and meaningful faculty contact at universities have been reported to fluctuate widely based on factors such as size and selectivity of the institution, student participation in research or pre-professional clubs, student perceptions of faculty members' attitudes towards students, and an interaction of student race and university location (Fischer, 2007; Hurtado et al., 2011). Lastly, a much larger proportion of respondents in the current survey indicated being in a club compared to the statistics reported by Colorado University as a whole, as well as by other universities (Hawkins, 2015; Carlson et al., 2024; Colorado State University, 2025b). This is to be expected due to the high percentage of respondents in the current survey that have an interest in applying for veterinary school following completion of a bachelor's degree. The American Association of Veterinary Medical Colleges recommends students interested in applying for veterinary schools should join clubs related to animal science and/or pre-veterinary medicine and gain as much hands-on experience with animals as possible during their undergraduate experience in order to make their applications stronger and more competitive (American Association of Veterinary Medical Colleges, 2025). Therefore, a population with a high concentration of students wanting to apply for veterinary school is likely to have a high proportion of respondents indicate club involvement.

The associations between final course grade and student involvement in the department from the current study align with results of previous studies conducted on undergraduates enrolled in science-based degree programs in universities across the United States. Sell et al. (2018) determined that involvement in undergraduate research was positively correlated with undergraduate GPA (Sell et al., 2018). Further, Hurtado et al. (2011) determined that being involved in research and/or clubs on campus is correlated to students interacting more with faculty members, and Komarraju et al. (2010) determined interactions with faculty are associated with improved academic performance. Thus, it can be concluded that engagement and involvement of undergraduate students have significant impacts on their grades. A student's level of engagement and involvement, both within a specific class and within the larger department or college, is often related to their sense of belonging within their university, college, and/or department (Wilson et al., 2015; Strayhorn, 2022). However, a student's sense of belonging and willingness to get involved are also often influenced by their demographic identities. For example, Hurtado et al. (2011) found that African American students at Historically Black Colleges and Universities reported higher engagement, better academic performance, and stronger relationships with professors than their peers at predominantly white institutions due to their enhanced feeling of belonging in that community (Hurtado et al., 2011). Further research is needed to fully understand the relationship between demographic factors, a student's sense of belonging, extracurricular involvement, and overall student success. Regardless of demographic factors, though, it has been reported that sense of belonging is influenced by positive interactions with faculty members and increased participation in extracurricular activities (Cwik and Singh, 2022; Strayhorn, 2022). Thus, faculty can support undergraduate success by encouraging departmental involvement, fostering inclusive professional learning communities, and building classroom- and department-wide environments that promote belonging for students of all identities and interests.

One specific form of involvement in the current study that was associated with reduced probability of failing was involvement in the daily care of department-owned dairy calves used for course activities and laboratory research. This aligns with a survey of undergraduate engineering students that describes a positive correlation between voluntary participation/involvement in additional hands-on learning opportunities and students' self-efficacy in engineering principles and practices, which is associated with overall academic achievement (Bartimote-Aufflick et al., 2016; Morocz et al., 2016). Numerous studies have shown the positive impacts of hands-on and experiential learning, including but not limited to increased comprehension and retention of practical/technical skills (Smith et al., 2005; Bradberry and De Maio, 2018; Robinson, 2023), improvement of strategic and critical thinking skills (Robinson, 2023), and increased student interest and motivation to participate and engage in learning (Reiling et al., 2003; Smith et al., 2005; Sullivan et al., 2023). It is likely due to these benefits, as well as numerous others, that hands-on on experiential learning opportunities have been seen to further increase a student's self-efficacy in their chosen discipline (Anderson et al., 2021). Although all students in the study had access to hands-on learning in lab sections, only about one-third volunteered for additional experiences such as feeding, monitoring, and medicating calves. Low participation may stem from systemic barriers such as transportation, work or family commitments, or lack of confidence with livestock. While such barriers cannot be eliminated entirely, reducing them could increase student involvement in extracurricular opportunities like calf care, which in this study was linked to lower predicted probabilities of failing ANEQ 101. Overall, offering opportunities for hands-on and experiential learning in animal sciences and continuously encouraging students to be involved in those opportunities can help improve their odds of succeeding academically in their chosen degree fields.

Some other academic behaviors were reported in the current study to be associated with lower probabilities of failing ANEQ 101 were having positive perceptions of self-adequacy in notetaking and study habits, perceived ease of studying for quizzes and exams, and positive attendance. However, no association was seen between the actual notetaking strategies or time spent studying and probabilities of failing. Much of recent research has highlighted the importance of good study skills and proper notetaking habits for student success, but few have defined the level of study skills by perceptions of adequacy on the part of the student. For example, a study by Sebesta and Speth (2017) reported improved examination scores for first-year college students in an introductory biology class for students that reported using self-regulated cognitive learning strategies taught in class to study, whereas those that did not utilize strong study skills did not improve on examination scores (Sebesta and Speth, 2017). However, the association was only seen between students performing certain study skills, without taking into account how students perceived the effectiveness of those skills. Further, a study by Mendezabal (2013) showed poor study habits among fourth-year college students, as defined by the Survey of Student Habits and Attitudes developed Holtzman et al. (1954), led to poorer scores on board examinations (Holtzman et al., 1954; Mendezabal, 2013). While the survey does ask about teacher approval and educational acceptance of study strategies used, it still doesn't factor in the component of how students feel about the adequacy of those skills for their own learning. For many students, it is likely those that have inadequate skills objectively are aware that this is the case, but there may be some students that utilize adequate techniques yet still feel their skills need improving to fit their own needs. Teaching self-regulated learning strategies encourages students to think critically, connect new material to prior experiences, and apply knowledge to real-world contexts rather than relying on rote memorization (Nilson, 2023). Instructors who explicitly teach how to learn and study effectively for specific courses can improve students' confidence in their study and notetaking abilities (McGuire, 2023), which in turn could help improve their odds of passing. However, societal barriers like the need to work while in school, which disproportionately affect first-generation and lower socioeconomic students (Pascarella et al., 2004; Green, 2021; Sokin, 2021), can limit how effectively these strategies enhance student success. This aligns with current study findings as well, which showed first-generation and students identifying as a non-minority race, which more often come from lower socioeconomic backgrounds compared to white-identifying students (American Psychological Association, 2017), had higher odds of failing compared to non-first-generation students and white-identifying students, respectively. Collectively, current findings paired with previous research show that students' perceptions of their own study abilities, combined with structural barriers that limit access to learning opportunities, play a critical role in academic success and should be central considerations when designing equitable support strategies.

Lastly, better attendance in both lecture and laboratory periods were associated with higher odds of passing ANEQ 101, which is corroborated by past studies showing positive correlations between attendance in a class and a student's final grade in that class (Halpern, 2007; McMillan et al., 2009; Khan, 2022). Student attendance, or lack thereof, is often impacted by social factors and personal choice on the part of the student (Sloan et al., 2020). Faculty have long advocated for improved attendance, and prior research shows that students themselves recognize the academic benefits of attending lectures (Alamoudi et al., 2021). Despite this, many students still choose not to attend for a variety of reasons—including early class times, the convenience of recorded lectures, conflicting responsibilities like exam preparation or work, and dissatisfaction with instructional quality. These decisions are often influenced by factors such as gender, GPA, and academic standing (Alamoudi et al., 2021). Further research is needed to explore effective strategies for promoting attendance as well as to assess whether course content should be adapted to better support students who cannot attend in person. Ultimately, understanding and addressing these barriers is essential for creating more inclusive and flexible learning environments.

The current study aligns with past research showing that departmental involvement, adequate and personalized learning strategies, and regular attendance can all increase a student's probability of passing a course. However, many of these opportunities are hidden behind societal and systemic barriers related to students' demographic and background characteristics that make it more difficult for all students to access them.

3.4.3 Demographic Factors Associated with Student Success

The second objective of the current study was to identify personal demographic and/or background characteristics of students that are associated with final course grade, regardless of a student's academic behaviors. Current results indicate that students retaking the course, those that are of a racially minoritized identity, and FG students with a HSGPA $\geq$ 4.00 have a higher probability of failing, compared to first-time enrollees, those identifying their race as white, and non-FG students with a HSGPA $\geq$ 4.00, respectively. The results regarding students retaking the course align with a study conducted on students enrolled in an introductory economics class in Canada that showed lower grades among students who had previously failed or withdrawn from the course compared to those of students taking the course for the first time (Armstrong and Biktimirov, 2014). However, the current study results regarding the effects of race are contradicted by past research. Only a small proportion of papers have explicitly explored the impact of race or ethnicity on student success matrices overall, and of those that have been done, no significant correlations have been reported between race or ethnicity and course grades, self-efficacy, or overall academic success in post-secondary education (Hackett et al., 1992; Lavoie, 2019). The fact that the current study found significant differences where past studies did not could be due to the large overall sample size and/or to the fact that the current study had a higher proportion of racially minoritized students compared to the previous literature examining the impact of race specifically within animal science. For example, in one recent study conducted at University of Nebraska-Lincoln by Lavoie et al. (2019), the study population consisted of only 193 students, 93% of which identified their ethnicity as Caucasian. The lack of variation in ethnicity in the study population in the Lavoie et al. paper could be why that study did not see an association between ethnicity and student final grade, student motivation, or self-efficacy. Lastly, numerous studies support the strength of HSGPA (Wesley, 1994; Geiser and Santelices, 2007; Kurlaender and Cohen, 2019) as a predictor of academic success in higher education, but none have explored the interaction between FG status and HSGPA in terms of overall success. However, one previous study does describe FG status as a strong predictor of HSGPA, which begins to illuminate the interconnectedness of the two demographic factors (Strayhorn, 2007). While results from the present study indicate that FG status among students with high HSGPA, student race, and number of times enrolled in the course are all related to students' final grade, further research is needed to understand the complexities of the relationships between demographic factors and how they impact student success.

By more specifically detailing the relationship between multiple demographic factors, as well as how they relate to a student's willingness and/or ability to perform certain academic behaviors, faculty can begin to tailor current support strategies for animal science students to increase equitability and effectiveness of these efforts. Current methods of supporting students identifying with certain demographic characteristics known to put them at an increased likelihood of failing vary by institution and demographic of interest. At CSU, students with poor high school performance are flagged as "Students Recommended for Support (SRS)" during admissions (Colorado State University, 2021) and all students are assigned a Support Priority Level each semester, with "High Priority" students intended to receive more advisor guidance (CSU Navigate, 2024). However, CSU's persistently low graduation rates suggest these systems do not fully meet student needs, potentially due to the influence of demographic factors on how support is experienced. For example, best practices at Historically Black Colleges and Universities (HBCUs) and Hispanic-Serving Institutions (HSIs) to support students of minoritized ethnic and/or racial identities include, but are not limited to, promoting inclusive faculty and student interactions, celebrating cultural identity and representation, providing multilingual academic support, and fostering the success of minoritized faculty members, all aimed at enhancing students' sense of belonging and satisfaction in their degree programs (Baker, 2013; Valentin, 2018; Garcia, 2023; Baldwin and O'Sullivan, 2025). Improved sense of belonging, community, and satisfaction in a college or degree program have been shown to improve academic success and graduation rates for all students, but especially those of minoritized identities (Suhre et al., 2007; Sinclaire, 2014; Baldwin and O'Sullivan, 2025). Further, all students, regardless of their identities, are more likely to be involved on campus and engaged in their coursework when they connect one-on-one with faculty members that are of a similar identity to themselves and/or are provided with opportunities to support or contribute to a community group they identify with (Palmer et al., 2011; Baldwin and O'Sullivan, 2025). However, according to recent reports by the National Center for Education Statistics, more than 70% of university faculty members nationwide are white (NCES, 2022), and only 15% of faculty at Colorado State University identify as an underrepresented race or ethnicity (Colorado State University Faculty Success, 2024). This limits the ability for students of minoritized identities to connect with mentors of similar identities and creates a barrier for belonging. Further, little is reported about other minoritized identities outside of race or ethnicity and how prevalent they are among faculty, nor about how the lack of representation might impact a student's sense of belonging on campus. Realistically, however, perfectly aligning faculty demographics to those of the students is nearly impossible, so further research needs to be conducted to explore ways to help students make meaningful connections on campus regardless of faculty demographics. In conclusion, demographic and background factors such as race, HSGPA, FG status, and times enrolled in a course do create systemic barriers to student success in higher education, but further research needs to be done to further define this impact and explore solutions to overcoming these barriers.

3.6 Conclusion

Overall, the success of first-year animal science students in an introductory food animal science course at CSU can be influenced by numerous factors, including their involvement in extracurricular activities, their propensity to connect one-on-one with faculty members, regularity of their attendance, and their perceptions of adequacy in the quality of their notetaking and study abilities. Additionally, student demographic and background characteristics such as race, high school GPA, first-generation status, and number of times enrolled in a course are directly associated with their final grades, where students of a minoritized race, those with high school GPA less than 4.0, first-generation students, and those repeating the course are more likely to fail. These demographic factors are also known to be indirectly related to course grade by affecting how the previously mentioned involvement, engagement, attendance, and learning habit factors impact course grade. To effectively support students in their first year, animal science programs should implement holistic approaches that combine academic interventions that promote course engagement, regular attendance, help students build individualized and effective learning strategies, create more culturally responsive support, and encourage more meaningful student-faculty interactions early on each semester. Future studies should be conducted to more explicitly define how academic behaviors and demographics impact other student success matrices, as well as promote contemporary teaching strategies that meet the needs of more diverse learners in animal science programs.

3.7 Tables and Figures

Table 3.1. *List of all variables included in final analysis, including variable type and levels of each variable.*

Variable Category	Variable Name	Variable Type	Variable Levels
Outcome	Final Grade	Binary	Pass *(Grades A, B, and C)*
			Fail *(Grades D and F)*
Predictor - Involvement	Research Involvement	Binary	Yes
			No
	Connecting with Faculty	Binary	Yes
			No
	Volunteering to Feed Calves	Binary	Yes
			No
	Club/Organization Involvement	Binary	Yes
			No
	Involvement (Comb.)	Binary	Yes *(Involved in ≥ 1 Listed Activity)*
			No *(Not Involved in Any Listed Activities)*
Predictor - Attendance	Lecture Attendance	Categorical	100% *(Missed 0 Lectures)*
			Almost 100% *(Missed 1-2 Lectures)*
			80-90% *(Missed 3-10 Lectures)*
			≤ 70% *(Missed ≥ 11 Lectures)*
	Laboratory Attendance	Categorical	100% *(Missed 0 Labs)*
			80-90% *(Missed 1-3 Labs)*
			≤ 70% *(Missed ≥ 4 Labs)*
Predictor – Learning Strategies	Perceived Adequacy of Notetaking	Binary	Yes *(Agree/Strongly Agree)*
			No *(Disagree/Strongly Disagree)*
	Perceived Adequacy of Study Habits	Binary	Yes *(Agree/Strongly Agree)*
			No *(Disagree/Strongly Disagree)*
	Experienced Difficulty Studying	Binary	Yes *(Agree/Strongly Agree)*
			No *(Disagree/Strongly Disagree)*

Table 3.1 (Cont.). *List of all variables included in final analysis, including variable type and levels of each variable.*

Variable Category	Variable Name	Variable Type	Variable Levels
Predictor – Learning Strategies (Cont.)	Need to Improve Studying/Notetaking	Binary	Yes *(Agree/Strongly Agree)*
			No *(Disagree/Strongly Disagree)*
	Time Spent Studying	Continuous	Number of Minutes Spent Studying
	Notetaking Methods	Categorical	No Notes
			Write a Few Notes on Printed Slides
			Write Many Notes on Printed Slides
			Write Notes on Blank Paper
			Write Notes on a Tablet/Computer with the Slides
			Write Notes on Blank Tablet or Computer
Predictor – Demographics and Background Factors	High School GPA (HSGPA)	Categorical	≥ 4.00
			3.00 – 3.99
			< 3.00
	Race	Binary	White
			Racially Minoritized
	Gender	Categorical	Cis Male
			Cis Female
			Transgender
			Other/Prefer Not to Say
	Times Enrolled in ANEQ 101	Binary	First-Time Enrollee
			Returning Enrollee
	Transfer Student Status	Binary	Yes
			No
	First-Generation Student Status	Binary	Yes
			No

Table 3.2. *List of all multivariable analysis models included in final analysis.*

Model Number	Predictor of Interest	Full Model	Final Model
1	Involvement (Comb.)	Final Grade ~ Involvement + HSGPA + Race + FG Status + Times Enrolled	Final Grade ~ Involvement + HSGPA + Race + Times Enrolled
2	Experienced Difficulty While Studying	Final Grade ~ Difficulty Studying + HSGPA + Race + FG Status + Times Enrolled	Final Grade ~ Difficulty Studying + HSGPA + Race + Times Enrolled
3	Perceived Need to Improve Study Skills	Final Grade ~ Perceived Need + HSGPA + Race + FG Status + Times Enrolled	Final Grade ~ Perceived Need + HSGPA + Race + Times Enrolled
4	Perceived Inadequacy In Time Spent Studying	Final Grade ~ Perceived Inadequacy + HSGPA + Race + FG Status + Times Enrolled	Final Grade ~ Perceived Inadequacy + HSGPA + Race + Times Enrolled
5	Perceived Personal Inadequacy of Notetaking Strategies	Final Grade ~ Perceived Inadequacy + HSGPA + Race + FG Status + Times Enrolled	Final Grade ~ Perceived Inadequacy + HSGPA + Race + Times Enrolled
6	Perceived Need to Improve Notetaking Strategies	Final Grade ~ Need to Improve Notes + HSGPA + Race + FG Status + Times Enrolled	Final Grade ~ Need to Improve + HSGPA + Race + Times Enrolled
7	Lecture Attendance	Final Grade ~ Lecture Attendance + HSGPA + Race + FG Status + Times Enrolled	Final Grade ~ Lecture Attendance + HSGPA + Race + Times Enrolled
8	Laboratory Attendance	Final Grade ~ Lab Attendance + HSGPA + Race + FG Status + Times Enrolled	Final Grade ~ Lab Attendance + HSGPA + Race + Times Enrolled
9	Demographics and Background Characteristics	Final Grade ~ HSGPA + Race + FG Status + Times Enrolled	Final Grade ~ HSGPA*FG Status + Race + Times Enrolled

Table 3.3. *Respondent demographics of the ANEQ 101 survey.*

Demographic Characteristic	n	Percentage
Gender		
Female	428	77.0%
Male	103	18.5%
Transgender Female	0	0.0%
Transgender Male	3	0.5%
Gender Variant/Non-Conforming	12	2.2%
Prefer Not to Say	5	0.9%
Other	2	0.4%
Race		
American Indian or Alaska Native	8	1.4%
Asian	22	4.0%
Black or African American	12	2.2%
Hispanic	83	14.9%
White	359	64.6%
Multiracial	65	11.7%
Other	3	0.5%
Year in Undergraduate Program		
Year 1	414	74.5%
Year 2	82	14.7%
Year 3	47	8.5%
Year 4	7	1.3%
Major (At Start of Course)		
Animal Sciences	492	88.5%
Other College of Agricultural Sciences Major	48	8.6%
Non-College of Agricultural Sciences Major	12	2.2%
Major (At End of Course)		
Animal Sciences	473	85.1%
Other College of Agricultural Sciences Major	57	10.3%
Non-College of Agricultural Sciences Major	21	3.8%
High School GPA (HSGPA)		
≥ 4.00	197	35.69%
3.00-3.99	335	60.69%
< 3.00	20	3.62%
Additional Respondent Characteristics		
First Time Taking ANEQ 101	535	96.2%
Pre-Veterinary Interest	370	66.5%
Enrolled in University Honors College	41	7.4%
Transfer Student	72	12.9%
Out-of-State Student	325	58.5%
First-Generation (FG) Student	171	31.32%

Table 3.4. *Bivariate analysis of the effects of all predictors of interest on students' final course grade in ANEQ 101.*

Predictor	X^2	*P*-Value
Involvement		
Connecting 1-on-1 with Faculty	7.5555	0.0060
Involvement in Department Research	6.2370	0.0125
Volunteering to Feed Laboratory Calves	10.3296	0.0013
Involvement in a Student Club or Organization	9.0229	0.0027
Notetaking		
Taking Notes in Class	0.1916	0.6616
Perceived Inadequacy in Personal Notetaking Ability	14.8373	< 0.0001
Perceived Need to Improve Notetaking	38.7610	< 0.0001
Study Habits		
Perceived Inadequacy in Time Spent Studying	8.6544	0.0033
Experienced Difficulty in Studying/Preparing for Quizzes and Exams	44.2019	< 0.0001
Perceived Need to Improve Study Skills/Habits	9.7583	0.0018
Time Spent Studying for Quizzes	2.7290	0.4353
Time Spent Studying for Exams	4..2735	0.3703
Attendance		
Lecture Attendance	26.1305	< 0.0001
Lab Attendance	26.8053	< 0.0001
Demographics		
High School GPA	13.1950	< 0.0001
Race	35.0766	< 0.0001
Times Enrolled in the Course	32.2150	< 0.0001
First-Generation Status	10.3071	0.0013
Transfer-Student Status	3.0447	0.0790
Gender	9.5190	0.1032

Table 3.5. *Multivariable analysis of the effects of student involvement on their probability of earning a failing grade in ANEQ 101. No significant interactions were observed, so main effects are reported for overall involvement (all involvement factors collapsed to indicate participation, or lack thereof, in at least one of the involvement factors) when controlling for HSGPA, Race, and times enrolled in the course.*

Predictor	Estimate	SE	*P* value	Predicted Probability of Failing ± SE (%)
Involvement				
Indicated Extracurricular Involvement	*Referent*	-	-	27.41 ± 6.41%
Did Not Indicate Extracurricular Involvement	0.7819	0.2804	0.0055	45.21 ± 9.11%
High School GPA				
≥ 4.00	*Referent*	-	-	15.82 ± 5.40%
3.00-3.99	1.0978	0.3593	0.0024	36.04 ± 6.16%
< 3.00	2.1667	0.6000	0.0003	62.14 ± 13.34%
Race				
White	*Referent*	-	-	23.01 ± 6.38%
Racially Minoritized	1.2493	0.2722	< 0.0001	51.04 ± 8.19%
Times Enrolled in ANEQ 101				
First-Time Enrollment	*Referent*	-	-	19.27 ± 3.31%
Not First-Time Enrollment	1.6987	0.5158	0.0011	56.61 ± 13.18%

Table 3.6. *Multivariable analysis of the effects of experiencing difficulty studying for exams on a student's probability of earning a failing grade in ANEQ 101. No significant interactions were observed, so main effects are reported for having experienced difficulty when studying (yes/no), when controlling for HSGPA, Race, and times enrolled in the course.*

Predictor	Estimate	SE	*P* value	Predicted Probability of Failing ± SE (%)
Experienced Difficulty Studying				
Yes	*Referent*	-	-	45.45 ± 8.68%
No	-1.4223	0.2979	< 0.0001	16.73 ± 5.24%
High School GPA				
≥ 4.00	*Referent*	-	-	12.39 ± 4.49%
3.00-3.99	1.0613	0.3627	0.0036	29.02 ± 5.80%
< 3.00	2.1253	0.6371	0.0009	54.23 ± 15.07%
Race				
White	*Referent*	-	-	18.25 ± 5.63%
Racially Minoritized	1.2114	0.2847	< 0.0001	42.85 ± 8.40%
Times Enrolled in ANEQ 101				
First-Time Enrollment	*Referent*	-	-	15.84 ± 2.98%
Not First-Time Enrollment	1.5537	0.5414	0.0043	47.08 ± 14.01%

Table 3.7. *Multivariable analysis of the effects of perceived personal inadequacy of notetaking strategies on a student's probability of earning a failing grade in ANEQ 101. No significant interactions were observed, so main effects are reported for indicating inadequacy in notetaking abilities (yes/no), when controlling for HSGPA, Race, and times enrolled in the course.*

Predictor	Estimate	SE	*P* value	Predicted Probability of Failing ± SE (%)
Perceived Inadequacy of Notetaking				
Yes	*Referent*	-	-	45.23 ± 9.98%
No	-0.8292	0.3319	0.0128	26.49 ± 6.35%
High School GPA				
≥ 4.00	*Referent*	-	-	16.29 ± 5.58%
3.00-3.99	1.0809	0.3573	0.0026	36.45 ± 6.47%
< 3.00	2.0120	0.6143	0.0011	59.27 ± 14.16%
Race				
White	*Referent*	-	-	21.98 ± 6.41%
Racially Minoritized	1.3217	0.2782	< 0.0001	51.37 ± 8.38%
Times Enrolled in ANEQ 101				
First-Time Enrollment	*Referent*	-	-	20.06 ± 3.81%
Not First-Time Enrollment	1.5532	0.5246	0.0032	54.25 ± 13.47%

Table 3.8. *Multivariable analysis of the effects of a student's demographic factors on their probability of earning a failing grade in ANEQ 101. A significant interaction was observed between HSGPA and FG status (P = 0.0397), so the interaction term effects are reported for HSGPA*FG status, when controlling for race and times enrolled in the course. The main effects for HSGPA and FG status are not reported.*

Predictor	Estimate	SE	*P* value	Predicted Probability of Failing ± SE (%)
High School GPA*First-Generation Status				
4.00 or higher				
First-Generation Student	*Referent*	-	-	22.46 ± 13.79%
Non-First-Generation Student	-1.8377	0.7541	0.0158	4.41 ± 3.99%
3.00 – 3.99				
First-Generation Student	*Referent*	-	-	31.08 ± 6.92%
Non-First-Generation Student	1.8530	0.7837	0.0184	31.51 ± 6.50%
Less than 3.00				
First-Generation Student	*Referent*	-	-	39.83 ± 21.23%
Non-First-Generation Student	2.7733	1.3057	0.0341	62.90 ± 16.87%
Race				
White	*Referent*	-	-	17.97 ± 5.52%
Racially Minoritized	1.2694	0.2939	< 0.0001	43.80 ± 8.23%
Times Enrolled in ANEQ 101				
First-Time Enrollment	*Referent*	-	-	15.83 ± 3.02%
Not First-Time Enrollment	1.5745	0.5132	0.0023	47.59 ± 13.41%

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5.1 SUPPLEMENTAL MATERIAL

5.1.1 Appendix A. LS Means for ECF TRT effects on calf health.

Least squares means for TRT effects on probability of having scours or respiratory disease, when controlling for sex and breed.

	Treatment				
	CON		COL		
Item	Estimate	SE	Estimate	SE	*P*-Value
Incidence of Scours	1.36	0.33	0.91	0.32	0.18
Incidence of Respiratory Disease	3.83	0.84	4.58	1.10	0.57

5.1.2 Appendix B. LS Means for ECF TRT effects on calf growth

Least squares means for TRT effects on growth/efficiency when controlling for sex and breed.

	Treatment				
	CON		COL		
Item	Estimate	SE	Estimate	SE	*P*-Value
Average Daily Gain					
First 2 Weeks (d 0-14)	0.71	0.06	0.76	0.06	0.39
Preweaned Period (d 0-56)	0.81	0.06	0.81	0.066	0.88
Feed:Gain					
Milk (L:kg)	7.06	1.81	9.07	1.81	0.24
Grain (kg:kg)	0.60	0.12	0.56	0.12	0.74

5.1.3 Appendix C. Student Success Survey Questions and Analysis Categories

Survey questions included in analysis and their analysis categories.

Outcome of Interest
What letter grade do you have currently in ANEQ 101? [c]
Predictor of Interest - Involvement
Have you reached out to and/or connected 1-on-1 with faculty? [a]
Are you involved in any research activities in the Department of Animal Sciences? [a]
Did you volunteer to help feed the dairy calves during the first 7 weeks of the semester? [a]
I have joined a student club or organization at CSU. [b]
Predictor of Interest – Notetaking
How have you been taking notes in ANEQ 101? [c]
The quality of my notetaking was inadequate. [b]
I need to improve my notetaking in courses like ANEQ 101. [b]
Predictor of Interest – Study Habits
How much time per week did you study/prepare for weekly quizzes in ANEQ 101? [d]
How much time per week did you study/prepare for the exams in ANEQ 101? [d]
I did not study as much as I should have. [b]
It was difficult for me to study/prepare for the quizzes and exams. [b]
I need to improve my study skills and habits in general. [b]
Predictor of Interest – Attendance
Approximately what percentage of lectures did you attend this fall in ANEQ 101? [c]
Approximately what percentage of laboratory periods did you attend this fall in ANEQ 101? [c]
Predictor of Interest – Demographics
Is this semester the first time you have ever enrolled in ANEQ 101 at CSU? [a]
At the start of the semester, what was your major at CSU? [d]
Currently, what is your major at CSU? [d]
What year are you currently at CSU? [c]
What is your gender? [c]
How would you best describe your race? [c]
What was your GPA in high school, on a 4.0 scale? [c]
I am enrolled in the honors program at CSU. [a]
I am the first generation in my family to attend college. [a]
I am an in-state student. [a]
I am a transfer student (and this is my first semester at CSU). [a]
I am interested in going to veterinary school. [a]

[a] Dichotomous measure [b] Likert scale measure [c] Multiple choice measure [d] Free response measure

5.1.4 Appendix D. Multivariate analysis of the impact perceived need to improve notetaking has on final grade in ANEQ 101.

Multivariable analysis of the effects of a perceived need to improve one's own notetaking strategies on that student's probability of earning a failing grade in ANEQ 101. No significant interactions were observed, so main effects are reported for perceived need to improve notetaking (yes/no), when controlling for HSGPA, race, and times enrolled in the course.

Predictor	Estimate	SE	*P* value	Predicted Probability of Failing ± SE (%)
Perceived Need to Improve Notetaking				
Yes	*Referent*	-	-	35.57 ± 7.46%
No	-1.5616	0.4527	0.0006	10.38 ± 4.81%
High School GPA				
≥ 4.00	*Referent*	-	-	8.81 ± 3.57%
3.00-3.99	1.1129	0.3742	0.0031	22.71 ± 5.68%
< 3.00	1.7750	0.6229	0.0046	36.29 ± 14.27%
Race				
White	*Referent*	-	-	12.23 ± 4.37%
Racially Minoritized	1.1919	0.2833	< 0.0001	31.45 ± 8.22%
Times Enrolled in ANEQ 101				
First-Time Enrollment	*Referent*	-	-	10.00 ± 2.56%
Not First-Time Enrollment	1.6437	0.5344	0.0022	36.51 ± 13.38%

5.1.5 Appendix E. Multivariate analysis of the impact lecture attendance has on final grade in ANEQ 101

Multivariable analysis of the effects of lecture attendance on their probability of earning a failing grade in ANEQ 101. No significant interactions were observed, so the main effects are reported for lecture attendance when controlling for HSGPA, race, and times enrolled in the course.

Predictor	Estimate	SE	*P* value	Predicted Probability of Failing ± SE (%)
Lecture Attendance				
100% (Missed 0 Classes)	*Referent*	-	-	14.58 ± 6.38%
Almost 100% (Missed 1-2 Classes)	0.6252	0.4715	0.1854	24.19 ± 6.94%
80-90% (Missed 3-10 Classes)	1.1686	0.4511	0.0099	35.46 ± 8.21%
< 70% (Missed ≥ 11 Classes)	1.6997	0.5956	0.0045	48.30 ± 11.63%
High School GPA				
≥ 4.00	*Referent*	-	-	12.43 ± 4.45%
3.00-3.99	1.1333	0.3600	0.0017	30.59 ± 5.91%
< 3.00	2.0420	0.6005	0.0007	52.23 ± 14.49%
Race				
White	*Referent*	-	-	17.51 ± 5.32%
Racially Minoritized	1.3115	0.2760	< 0.0001	44.06 ± 8.14%
Times Enrolled in ANEQ 101				
First-Time Enrollment	*Referent*	-	-	17.16 ± 3.27%
Not First-Time Enrollment	1.3599	0.5351	0.0113	44.66 ± 13.47%

5.1.6 Appendix F. Multivariate analysis of the impact lecture attendance has on final grade in ANEQ 101

Multivariable analysis of the effects of laboratory period attendance on their probability of earning a failing grade in ANEQ 101. No significant interactions were observed, so the main effects are reported for laboratory attendance when controlling for HSGPA, race, and times enrolled in the course.

Predictor	Estimate	SE	*P* value	Predicted Probability of Failing ± SE (%)
Laboratory Period Attendance				
100% (Missed 0 Labs)	*Referent*	-	-	23.24 ± 7.27%
80-90% (Missed 1-3 Labs)	0.5048	0.3018	0.0950	33.40 ± 7.45%
< 70% (Missed ≥ 4 Labs)	1.4985	0.5590	0.0076	57.53 ± 13.84%
High School GPA				
≥ 4.00	*Referent*	-	-	16.58 ± 5.90%
3.00-3.99	1.1965	0.3603	0.0010	39.67 ± 7.43%
< 3.00	2.0687	0.6160	0.0008	61.14 ± 14.31%
Race				
White	*Referent*	-	-	23.79 ± 7.07%
Racially Minoritized	1.3115	0.2760	< 0.0001	52.74 ± 9.09%
Times Enrolled in ANEQ 101				
First-Time Enrollment	*Referent*	-	-	20.72 ± 4.13%
Not First-Time Enrollment	1.6293	0.5451	0.0029	57.14 ± 14.14%

5.1.7 Appendix G. Bivariate analysis between demographic factors and other predictors of student success in ANEQ 101.

Bivariate analysis between significant demographic factors and each predictor of interest significantly associated with a student's probability of earning a failing grade in ANEQ 101. *P*-values are reported for each combination of predictors, with bolded terms indicating significant association ($P < 0.05$).

Predictor	Times Enrolled	First-Generation Status	HSGPA	Race
Involvement				
Involvement (Combined)	0.3460	0.0850	**< 0.0001**	**0.0217**
Connecting 1-on-1 with Faculty	0.5769	0.5425	**0.0046**	0.5481
Involvement in Department Research	0.2429	0.1836	**0.0009**	0.1894
Volunteering to Feed Laboratory Calves	0.3715	0.4524	**0.0416**	**0.0159**
Involvement in a Student Club or Organization	0.0713	**0.0303**	**0.0002**	**0.0033**
Perceived Inadequacy of Notetaking				
Perceived Inadequacy in Personal Notetaking Ability	**0.0187**	**0.0253**	0.2501	**0.0102**
Perceived Need for Improved Notetaking	0.1633	**< 0.0001**	**< 0.0001**	**< 0.0001**
Perceived Inadequacy of Study Habits				
Perceived Inadequacy in Time Spent Studying	0.6538	**0.0396**	0.0501	**0.0003**
Experienced Difficulty in Studying or Preparing for Quizzes and Exams	**0.0121**	**0.0080**	0.0832	**< 0.0001**
Perceived Need for Improvement in Study Skills/Habits	0.4942	**0.0009**	**0.0002**	**0.0002**
Attendance				
Lecture Attendance	**< 0.0001**	0.4211	**0.0022**	0.2649
Lab Attendance	**0.0020**	0.4407	**0.0086**	0.1508
Demographics				
Times Enrolled	-	0.0518	0.1442	**0.0001**
First-Generation Status	0.0518	-	**0.0135**	**< 0.0001**
HSGPA	0.1442	**0.0135**	-	0.0763
Race	**0.0001**	**< 0.0001**	0.0763	-

5.1.8 Appendix H. ANEQ 101 Student Success Survey Questions

Questions included in the 2023 student survey used for data collection that was distributed to all students enrolled in ANEQ 101.

SECTION 1 – COURSE OVERVIEW

1. Is this semester the first time you have ever been enrolled in ANEQ 101 at CSU?
    a. Yes
    b. No

2. How would you rate the quality and value of information you were provided in ANEQ 101?
    a. Very high quality
    b. High quality
    c. Average
    d. Low quality
    e. Very low quality
        Comments:

3. Did ANEQ 101 meet your expectations?
    a. Yes
    b. No
        If no, what was the primary reason why not?

4. What did you think about having other faculty members from the Department of Animal Sciences guest lecture in ANEQ 101?
    a. Even more guest lectures should be included from faculty, including on all topic areas
    b. The number of faculty members that provided guest lectures was appropriate
    c. Fewer faculty members should provide guest lectures
    d. It would be best to have 1 main instructor provide all lecture material
        Comments:

5. Of the following faculty member(s) who guest lectured, indicate which you enjoyed the **most** with an "**M**" (maximum of 2) and which you enjoyed the **least** with an "**L**" (maximum of 2)?

__ Lily Edwards-Callaway (An Ethics/Welfare)
__ Mahesh Nair (Meat Science)
__ Shawn Archibeque (Nutrition)
__ Noa Roman-Muniz (Lactation)
__ Temple Grandin (Animal Handling)
__ Libby Bigler (Beef Quality Assurance)
__ Pablo Pinedo (Reproduction)
__ Caitlin Cadaret (Reproduction)
__ Stephen Coleman (Genetics)
__ Scott Speidel (Animal Breeding)
__ Jennifer Martin (Meat Palatability - Lab)
__ Mesa Kutz (Livestock Judging - Lab)
__ Catie Cramer (Calf Health, Dairy Production)
__ Haley Cole (Meat Judging - Lab)
__ Jessica Metcalf (Microbiome)

6. This fall, have you reached out to and/or connected 1-on-1 with a faculty member who guest lectured in ANEQ 101?
    a. Yes
    b. No

        If yes, who was the faculty member?

7. Was it valuable to have lecture notes (i.e., printed slides) handed out before each lecture?
    a. Yes
    b. No

        Comments:

8. Should topics about companion animals, wildlife, and/or exotic species be included in ANEQ 101 or another introductory course, or should ANEQ 101 maintain its focus on food animals?
    a. Yes, include other topics
    b. No, maintain food animal focus in ANEQ 101

        Comments:

9. Please provide any additional comments related to the **lecture** portion of ANEQ 101:

SECTION 2 – COURSE PERFORMANCE

10. Prior to the first day of class, what letter grade did you think you would achieve in ANEQ 101 this fall?
    a. A
    b. B
    c. C
    d. D
    e. F

11. Approximately, what letter grade do you have currently in ANEQ 101?
    a. A
    b. B
    c. C
    d. D
    e. F

12. What final course letter grade are you likely to receive in ANEQ 101 at the end of this semester?
    a. A
    b. B
    c. C
    d. D
    e. F

13. Approximately how much time per week did you study/prepare for the weekly **quizzes** in ANEQ 101 this semester?
    ___ minutes (or___ hours) per quiz

14. Approximately how much time per exam did you study/prepare for the 2 **exams** in ANEQ 101 this semester?
    ___ minutes (or___ hours) per exam

15. Were you also enrolled in ANEQ 180A2 Exploring Student Success (1 credit) this semester?
    a. Yes
    b. No

16. How have you been taking notes in ANEQ 101 this fall?
    a. I don't really take notes, but I listen and follow along with the slides instead
    b. I write a few notes on the printed slides that are handed out
    c. I write a lot of notes on the printed slides that are handed out
    d. I take a lot of notes separately in a notebook and not on the printed slides
    e. I take notes on a tablet or other electronic device that has the slides on it
    f. I take notes on a blank tablet or other electronic device (with no slides on it)
    g. Other: ________________________

17. Approximately what percent of the 3-times-a-week **lectures** (M, W, F at 10:00-10:50 am) did you attend this fall in ANEQ 101? (mark only one)
    a. 100% (I didn't miss a single lecture)
    b. Almost 100% (I missed ~1-2 lectures)
    c. ~90% (I missed ~3-5 lectures this semester)
    d. ~80% (I missed ~6-10 lectures this semester – about 1 every other week)
    e. ~70% (I missed ~11-15 lectures this semester – about 1 per week)
    f. ~60% (I missed ~16-19 lectures this semester – more than 1 per week)
    g. ~50% or less (I missed ~20-25 or more lectures this semester – up to 2 per week)
       <u>Comments</u>:

18. On days that you did <u>NOT</u> attend **lecture**, what was the primary reason?

19. What was your GPA (grade point average) in high school, on a 4.0 scale (i.e., out of 4.0)?
    a. Greater than a 4.0 (this can occur in some Colorado high schools)
    b. Very close to a 4.0
    c. 3.5 to 3.9
    d. 3.0 to 3.4
    e. 2.5 to 2.9
    f. 2.0 to 2.4
    g. Below a 2.0

20. Are you involved in any research activities in the Department of Animal Sciences?
    a. Yes
    b. No
    If yes, was this involvement a result of your enrollment in ANEQ 101?

21. What are some main reasons that you may not do as well in this course as you had originally hoped? (**mark all that apply**)
    a. I am getting the grade I had hoped for
    b. Course material was too difficult to comprehend
    c. The amount of material was overwhelming
    d. Not enough review sessions or help sessions were provided
    e. I did not study as much as I should have
    f. I did not attend lectures or labs as much as I should have
    g. I missed too many quizzes
    h. I did not turn in at least 1 homework assignment
    i. The quality of my notetaking was inadequate
    j. It was difficult for me to study/prepare for the quizzes and exams
    k. I did not take this course seriously
    l. Other: _________________________

22. When considering obstacles or challenges that may have prevented you from being as successful in ANEQ 101 as you wanted, please provide your level of agreement with each of the following statements: *(SA = Strongly Agree, A = Agree, D = Disagree, SD = Strongly Disagree)*

Financial challenges were an obstacle to my success	SA	A	D	SD
Legal challenges were an obstacle to my success	SA	A	D	SD
Family responsibilities were an obstacle to my success	SA	A	D	SD
Mental health challenges were an obstacle to my success	SA	A	D	SD
Physical health challenges were an obstacle to my success	SA	A	D	SD
Learning challenges were an obstacle to my success	SA	A	D	SD
Work responsibilities were an obstacle to my success	SA	A	D	SD
Something else was an obstacle to my success: ___________	SA	A	D	SD

SECTION 3 – WEEKLY LABS

23. Who was the **lab instructor** for your face-to-face weekly **lab** section?
    a. Jason Ahola (Mon 12:00-1:50 pm)
    b. Lexie Miller (Mon 2:00-3:50 pm)
    c. Tyler Thomas (Tues 11:00-12:50 pm)
    d. Abbey Schiefelbein (Tues 3:00-4:50 pm)
    e. Rachael Stucke (Wed 1:00-2:50 pm)
    f. Claire Okoren (Wed 3:00-4:50 pm)
    g. Erica Machuca (Thur 11:00-12:50 pm)
    h. Paxton Sullivan (Thur 3:00-4:50 pm)

24. Approximately what percent of ANEQ 101 once-a-week **labs** did you attend this fall?
    a. 100% (I didn't miss a single lab)
    b. ~90% (I missed 1-2 labs all semester)
    c. ~80% (I missed ~3 labs this semester)
    d. ~70% (I missed ~4-5 lectures this semester)
    e. ~60% (I missed ~6 labs this semester)
    f. ~50% or less (I missed ~7 or more labs this semester)

25. On days you did <u>NOT</u> attend **lab**, what was the primary reason?

26. Of the following lab topics from this semester, indicate which you enjoyed the **MOST** with an "**M**" (maximum of 3) and which you enjoyed the **LEAST** with an "**L**" (maximum of 3)?
    __ *Calf handling and anatomy (week 2)
    __ *Calf health evaluation (week 4)
    __ *Calf BQA procedures (week 5)
    __ *Calf management/castration (week 6)
    __ Digestive tract dissection (week 7)
    __ Reproductive tract dissection (week 8)
    __ Meat product tasting (week 9)
    __ Livestock evaluation at ARDEC (week 10)
    __ Sheep handling at ARDEC (week 11)
    __ ARDEC facility tour (week 12)
    __ Dairy product processing & tasting (week 13)
    __ Meat evaluation and facility tour (week 14)
    __ Quiz Bowl (week 15)
    **These labs were held at foothills*

    <u>For the above lab topics that were your **MOST** desirable, why did you like them</u>?

    <u>For the lab topics that were your **LEAST** desirable, why did you not like them</u>?

27. Did you volunteer to help feed the dairy calves during the first 7 weeks of the semester?
    a. Yes
    b. No
    <u>If yes, approximately how many total times did you help feed calves</u>?

    <u>If you volunteered, please describe any value this experience provided to you:</u>

28. Did using dairy calves in 4 labs at the beginning of the semester help with your learning?
    a. Yes
    b. No
    If yes, please elaborate…

29. Should we include the dairy calf project in future labs in ANEQ 101?
    a. Yes
    b. No
    Please elaborate on your answer…

30. Are there specific aspects of the ANEQ 101 dairy calf project that should be changed?

  a. Yes
  b. No

  If yes, please explain…

31. What topic(s) or activities would you suggest being added as a **lab session** in the future?

32. Relative to your **lab instructor**, please provide your level of agreement with each of the following statements: *(SA = Strongly Agree, A = Agree, D = Disagree, SD = Strongly Disagree)*

My lab instructor…

…was organized, prepared, and used lab time efficiently	SA	A	D	SD
… explained topics clearly and was easy to understand	SA	A	D	SD
…was accessible and helpful outside of lab time (including via email)	SA	A	D	SD
…encouraged student participation during lab	SA	A	D	SD
…stimulated my interest in the topic	SA	A	D	SD
…cared about students, including them being successful	SA	A	D	SD
…created a welcoming and inclusive environment	SA	A	D	SD

33. In general, what did your **lab instructor** do well?

34. In what ways could your **lab instructor** improve as a teacher?

35. Please provide any additional feedback regarding the **lab** portion of this course:

SECTION 4 – CHALLENGES

36. Regarding ANEQ 101 and the Department of Animal Sciences, please provide your level of agreement with each of the following statements: *(SA = Strongly Agree, A = Agree, D = Disagree, SD = Strongly Disagree)*

I ask questions in ANEQ 101 **lecture**	SA	A	D	SD
I ask questions in ANEQ 101 **lab**	SA	A	D	SD
I take detailed notes during ANEQ 101 lectures and labs	SA	A	D	SD
I keep track of ANEQ 101 assignment due dates, quizzes, and exams in a calendar	SA	A	D	SD
I need to improve my notetaking in courses like ANEQ 101	SA	A	D	SD

37. Regarding ANEQ 101 and the Department of Animal Sciences, please provide your level of agreement with the following statements: *(SA = Strongly Agree, A = Agree, D = Disagree, SD = Strongly Disagree)*

I am satisfied with simply passing all my classes (i.e., C grade)	SA	A	D	SD
I need to improve my study skills and habits in general	SA	A	D	SD
I need to accept greater responsibility for my actions (attending class, studying, completing assignments)	SA	A	D	SD

I need to improve how I manage my time	SA	A	D	SD
ANEQ 101 is an academically rigorous course	SA	A	D	SD
The Animal Science major is the right major for me	SA	A	D	SD

38. Regarding ANEQ 101 and the Department of Animal Sciences, please provide your level of agreement with the following statements: *(SA = Strongly Agree, A = Agree, D = Disagree, SD = Strongly Disagree)*

I have attended instructor and/or TA office hours for ANEQ 101	SA	A	D	SD
I have joined a student club or organization at CSU	SA	A	D	SD
I feel welcomed in the Department of Animal Sciences as I am	SA	A	D	SD
My instructors make me feel safe to participate in ANEQ 101	SA	A	D	SD
Other students make me feel safe to participate in ANEQ 101	SA	A	D	SD
I intend to return to CSU in the Spring semester	SA	A	D	SD

If you answered D or SD, what is the primary reason you may not return?

39. Has your experience in ANEQ 101 and the Department of Animal Sciences been what you expected it would be?
    a. Yes
    b. No
        If no, please elaborate on your answer…

SECTION 5 – DEMOGRAPHICS

40. At the start of the fall semester, what was your major at CSU?

41. Currently, what is your major at CSU?
42. What year are you at CSU currently?
    a. Freshman
    b. Sophomore
    c. Junior
    d. Senior

43. What is your gender?
    a. Female
    b. Male
    c. Transgender female
    d. Transgender male
    e. Gender variant / non-conforming
    f. Not listed: _________________
    g. Prefer not to answer

44. How would you best describe yourself?
   a. White
   b. Hispanic
   c. American Indian or Alaska Native
   d. Black or African American
   e. Asian
   f. Multiracial
   g. Other: ____________

45. Please indicate your preference for meat consumption:
   a. I am a meat eater
   b. I am a vegetarian (I don't eat meat, but I do consumer or use other animal products)
   c. I am a vegan (I don't consume or use any products from animals)
   d. Other: _________________

46. Please respond to the following statements. Circle one:

I am enrolled in the honors program at CSU	Yes / No
I am the first generation in my family to attend college	Yes / No
I am an in-state student	Yes / No
I am a transfer student (and this is my first semester at CSU)	Yes / No
I am living away from home for the first time this fall	Yes / No

47. Please respond to the following statements: Circle one:

Before ANEQ 101, I had prior experience with food animal livestock	Yes / No
Before ANEQ 101, I had prior experience with non-food animal livestock (i.e., horses, alpacas, llamas, etc.)	Yes / No
My only animal experience is with companion animals (dogs, cats)	Yes / No
Growing up, I participated in a livestock project in 4-H and/or FFA	Yes / No
I am interested in going to veterinary school	Yes / No
I am interested in a career in the food animal production industry	Yes / No
I am interested in a career working with companion animals (dogs, cats)	Yes / No
I am interested in a career working with wildlife or exotic animals	Yes / No
During this fall semester I have considered changing my major at CSU	Yes / No

48. Do you currently work while attending CSU?
   a. Yes
   b. No

      If yes, approximately how many hours per week do you work?
      a. 1-10 hours / week
      b. 11-20 hours / week
      c. 21-30 hours / week
      d. 31-40 hours / week
      e. 41 or more hours / week