THESIS

AN INTEGRAL APPROACH FOR MANAGEMENT CHALLENGES IN THE DAIRY INDUSTRY

Submitted by

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ABSTRACT

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A growing body of literature recognizes the importance of including an integrated approach to animal welfare and employee well-being in the dairy industry. The current thesis aims to describe this integral approach by presenting two research projects developed in a commercial dairy under the same management. Hence, an animal welfare pilot study was performed on a dairy farm located in northern Colorado, and an employee well-being study was developed on three dairy farms, two located in northern Colorado and one in northern Texas. Both projects were performed during the year 2022 and the dairies are administrated by the same management.

The overall structure of this thesis takes the form of three chapters, including each perspective previously analyzed in the current management challenges explored in the dairy industry. Chapter one presents an extensive literature review of both approaches identified as management challenges in the dairy industry. Then, chapter two analyses the results of an online survey undertaken from September through November 2022 that aimed to explore employee adaptation, perception, and understanding of technology in the dairy farm. In order to accomplish the goal of this pilot study, the online survey completed by two-hundred-sixty-six employees was analyzed and the results are presented in chapter two. Chapter three presents the results of an observational study done on cow-calf behavior from the expulsion of the calf up to the separation in a dairy system located in northern Colorado. One-hundred-sixty-seven calving that occurred from May to June were analyzed and the results are presented in chapter three.

Results are briefly described next. First, from the adaptation, perception, and understanding of technology in the dairy farm study, employees recognize and have positive feelings towards the technology implemented at work, where they highlighted the understanding of its benefits, and recognized the technology as a tool that helps them to be more efficient. However, the challenges to adapting to new technology were mainly determined to be personal limitations, such as not knowing the language of the technology and impairments to seeing. Also environmental limitations were recognized by the employees such as cold weather, wind, or an environment that is too dark or too bright. Lastly, the level of perception of technology was found to be associated with the level of education and level of English of the employee, but no significant differences were identified by age or gender. Findings are promising and the current thesis invites the academia to extended this type of research in other livestock operations that adopt precision livestock farming technology.

Second, from the cow-calf behavior from the expulsion of the calf up to separation in a dairy system research, with an average time of 2,489 seconds together, the predominant behavior found by the dam was the intensive licking towards their calf, and secondary particular behaviors were lying down after calving, aggressive behavior upon a surrogate cow, and a following behavior upon separation. On the calf side, the main behaviors were licking the cow, and mobilizing with their two front hooves. Less common behaviors were standing up, reaching the udder, suckling, and looking at her cow upon separation. Moreover, animal-level variables that were associated with these behaviors were found to be parity and calving difficulty.

Also, for environmental-level variables, the drop time, calving in the patio, and temperature were associated with these behaviors as well. In general, no significant associations were found for twins, calf gender, and heat index. Lastly, when the future health performance of both animals was analyzed, only the stand-up behavior of the calf was significantly associated with an increased average daily gain weight from birth to weaning, compared to calves that did not stand up.

The novel findings presented in this thesis will help dairy management to better understand latent challenges in the industry with an integral approach that includes animal welfare and employee well-being. This study extends the knowledge of cow-calf contact systems by exploring the animal behavior right after calving and up to separation and provides a comprehensive assessment of adaptation, perception, and understanding of precision livestock farming technologies by the dairy employee. The conclusions from this thesis will add to the rapidly expanding field of integrating animal and employee health into integral strategies for current management challenges in the dairy industry.

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CHAPTER 1: INTRODUCTION

The dairy industry management in the United States has been included in a transdisciplinary approach that aims to attain optimal health and sustainability for animals, humans, and the environment (Prata et al., 2022). Moreover, this industry has undergone a rapid structural change in the last decades with improved operation efficiency in larger herds with fewer farms, resulting in multiple management challenges to operate human and animal health, while maintaining environmentally sustainable. Therefore, dairy science has been invited to have a multidisciplinary inclusion of these three pillars in research projects, as a potential insight for better management practices within the industry (2022). Thus, the main goal of the current thesis is to determine an integral approach to current management challenges in the dairy industry, including employee well-being and animal welfare.

During the planning stage of the current research, employee well-being and animal welfare were highlighted as top priorities to analyze latent challenges for the dairy industry management. On one side, the employee's well-being resulting from the rapid adoption of Precision Livestock Farming (PLF) technology in dairy farms has not been detailed investigated and has been exclusively determined by the dairy owner or management. This interaction of the dairy employee with the PLF has been proposed in this thesis under an integral approach due to its implication in animal care and handling. Hence, the PLF is a tool that helps connect the employee with the animal according to its primary objective, for example, information recorded in animal software would allow an employee to determine the needs of the animal in terms of nutrition, reproduction, production, and welfare. Consequently, the comprehension of how dairy employees adapt, perceive, and understand the PLF technology in their daily operations is a key driver that would help improve the adoption of PLF technologies, and would provide insights for technology manufacturers to provide a more user-friendly system for the end-user (farm employee). Thus, this study set out to gain a further understanding of how dairy employees recognize and use PLF technologies in their daily routines.

Moving to the animal welfare aspect, the conversation about cow-calf contact systems was considered a relevant concern among stakeholders that has evolved over time and that needs special attention for farm management (Neave et al., 2022), thus, society's expectations in the dairy industry has pushed the dairy operations to implement different cow-calf contact systems in order to maximize animal welfare in the farm. However, the study of the benefits and challenges of both contact systems, immediate separation, or prolonged separation, have been limited and not clearly understood by dairy management and should be extended in research (von Keyserlingk & Weary, 2017). Moreover, a detailed understanding of cow-calf behavior right after calving should be considered when interpreting the benefits and challenges of cow-calf contact systems. The current thesis aims this, by studying the behavior of the dam and the calf right after calving and up to separation, and its association with animal-level and environmental variables, as an insight for further research in cow-calf contact systems.

An extensive review of the literature for both approaches, employee well-being, and animal welfare, has been included in this first chapter as a piece of meaningful evidence to support the reason of the current thesis. Therefore, the purpose of the following section is to review recent research into employee well-being for employee adaptation, perception, and understanding of technology in the dairy farm, and current research into the animal welfare approach for cow-calf behavior from the expulsion of the calf up to separation in a dairy system.

1. Employee adaptation, perception, and understanding of technology in the dairy farm.

For the purpose of this study, it is necessary to define the concept of Precision Livestock Farming (PLF), then describe the study approaches available for technology adoption in the United States dairy farm and how they have been reviewed, and the implications for further research.

1.1 Precision Livestock Farming definition

The precision technology implemented in the dairy industry has been included in a wider conceptual term, Precision Livestock Farming (PLF) or Precision Livestock Technology (PLT), which is broadly defined by Berckmans (2017) as a tool that offers real-time monitoring of animal health, welfare, production/ reproduction, environmental impact, PLF encompasses management systems for farmers by delivering a real-time warning to the farmer to take immediate action. The idea of PLF has been dated since the adoption of individual automated milk meters for cattle in 1992, described as a technology that revolutionized dairy farming (Morrone et al., 2022). Hereby, the understanding behind the performance of PLF relies on two stages, first, the transformation of criteria collected by the production system (Banhazi et al., 2012), including milking machines and robots, sorting gates, feeding robots, animal wearable devices (RFID, collars, pedometers, calving sensors), Artificial Intelligence (AI) devices, sensors for Body Condition Score (BCS), lameness score, milk quality, and other animal health and performance devices. Secondly, the criteria should be translated within the operating system so that can be controlled and interpreted by management to maximize its efficiency and productivity.

In livestock systems production, PLF has been extensively reviewed for its current application in different farming systems and has been categorized based on its application (Morrone et al., 2022), including technology for animal behavior, animal performance, and feed monitoring, disease detection systems, oestrus detection systems, milking systems, and identification and tracking systems. Likewise, technologies recognized in these categories are automatic accelerometers, Automated Milking Systems (AMS) robots, weighing platforms, electronic gates, heartbeat sensors, Radio Frequency Identification (RFID), skin temperature sensors, Infrared thermography (IRT), electronic drinkers and feeders, Ultra-wideband localization systems (UWB), video frames extraction and environmental temperature and humidity sensors (2022).

To understand the practical application of PLF in dairy operation is important to highlight that effective implementation of PLF technologies requires the integration of three specific inputs (Berckmans, 2006); animal variables (ex. Milk production per cow, heat cycle, BCS, the health status of the cow, social interactions among cows, and so), expected variation in response of those animal variables, and predictions from logarithms models. The transformation of the animal variables into data sets that will estimate and predict variables and models is achieved using Artificial Intelligence (AI) and machine learning (ML). A practical example is sensor technology, in which biochemical, emotional, and physiological variables of the animal are captured and then codified in logarithms that translate information able to predict animal productivity and disease resilience of the animal (Neethirajan, 2020).

Additionally, the implementation of PLF in the dairy industry has developed as a response to the current progress in ML and AI technologies. A prominent systematic review of published literature (129 publications worldwide) related to the application of machine learning technology in dairy research concluded that most of the data from machine learning technology applications originate from the United States (Shine & Murphy, 2021). Including data on the physiology and health of dairy cows, analyses of animal behavior, animal husbandry, farm management, milk, and feeding. The main technology linked with the collection of this data has been the image, accelerometers, and pedometer sensors. Also, there has been a significant increase in the research publication on machine learning since 2018, which makes the application of technologies a trending topic in the dairy industry and livestock operations overall.

In this thesis, the term PLF will be used in its broadest sense to refer to all technologies implemented in the dairy operation, including the main categories of the system such as nutrition, genetics, reproduction, production, animal behavior, and welfare, and other areas related to the dairy operation like maintenance, grazing and pasture management.

1.2 Adoption of new technologies in the dairy farm

Most studies have focused on how likely management will adopt or implement new technology in the dairy operation, depending on farmer profile and farm characteristics, and how the technology tools would impact their operation and profitability (Abeni et al., 2019; Bianchi et al., 2022; Borchers & Bewley, 2015; Jago et al., 2013; Silvi et al., 2021). The methodology approach used in those studies is similar, with a targeted survey distributed to dairy farmers, mainly in the management position, either in Italy, the United States, Brazil, Australia, and other countries not disclosed. On the whole, those studies aimed to show the likelihood to adopt new technology and the challenges associated with its implementation. Those results demonstrated that dairy farmers commonly adopt automated milk yield recording technologies and sensor systems to detect mastitis, cow activity, and estrus detection. Likewise, dairy farmers indicated the challenges they face when implementing technology in the operation, including the time required to manage the data, the total investment cost and benefit-to-cost ratio, and the lack of integration with other on-farm systems. A major current focus was given to the future implication of PLF and the understanding of the technology perception, to provide an improved user-friendly system, develop training initiatives for farmers and better integration with manufacturers for technical support, and better design that aligns with dairy farm needs.

Few studies have also identified advantages of the interaction between humans and technology, by studying the owner's, or main farmer, perceived benefits. A well-known example is the adoption of milking automatization, where farmers have shifted from conventional milking (by hand) to Automatic milking systems (AMS) and automatic milking rotaries (AMR). This shift has been associated with an improved farmer's quality of life (Hostiou et al., 2017) because farmers can save time for their daily routine or other dairy operation while automating milk production. This efficiency has been estimated to be 18% in labour efficiency together with an increase of up to 12% in milk production (Jacobs & Siegford, 2012).

Overall, the results from studies related to the adoption and understanding of PLF have highlighted the exclusion of the end user (the employee) from the technology development (Huirne et al., 1997), where manufacturers lack understanding and consider the dairy farmer's perception (Borchers & Bewley, 2015), resulting in a poor understanding of the technologies available. Likewise, researchers point out the importance of considering the attributes of technology, interactions, and psychological factor as variables that might influence effective technology diffusion, rather than just the size of the farm and operator characteristics (Shang et al., 2021). Thus, there remains a need for an efficient method that can describe employee adaptation, perception, and understanding of technologies in dairy systems.

1.3 Implications for further research in precision technology

A meaningful highlight from the literature reviewed above is to consider the impact of the current research on the dairy industry and livestock operations overall. The use of data from PLF technologies is extensively used in any dairy operation and the livestock industry by all the stakeholders involved, such as the operator, the academia, the technology manufacturer, and the consumer. Thus, to point out how significant the clear understanding of the technology by the employee in the livestock operation is, there must be a consideration that the data is a result of a technology the employee constantly uses in their daily routine, and the employee might enter information to this technology. Even this challenge has been considered by IoT (Internet of Things) experts where it has being pointed out that despite the efforts to leverage intelligence solutions with IoT, the technology used in livestock operations is still operated by people (Werkheiser, 2020). Thus, the adoption of new technology by dairy producers has to consider the integral approach of sustainability, comprising economic sustainability, environmental sustainability, and social sustainability. Daniela Lovarelli et al., (2020) describe these pillars as the inclusion of the economic investment (initial, operational, and maintenance cost), the social effect on animal welfare and the dairy worker's well-being, and its environmental implication.

The current study aims to contribute to this growing area of research by exploring the technology adaption, perception, and understanding, which were considered the substantial categories to find opportunities for the effective adoption of technologies in dairy operations by the employee. First, the adaption refers to how the employee uses their knowledge and/ or resources in the dairy operation to familiarize themselves with the technology they have to use in their daily tasks, then, the perception is described as the employee's awareness of how the technology benefits its daily routine, challenges they might face when using the technology, and personal point of view of benefits and limitations. And the understanding of technology denotes considering how familiar the employee is with the technology and exploring how the employee recognizes its benefits for the operation and their job.

2. Cow-calf behavior from the expulsion of the calf up to separation in a dairy system

For the aim of this study, it is necessary to define the concept of animal behavior, then describe the study approaches available for early cow-calf contact and prolonged cow-calf contact systems and how they have been reviewed, and the implications for further research. Early cow-calf contact has been described as immediate calf removal, or up to 72 hours postpartum. While prolonged cow-calf separation is longer than this time.

2.1. *Animal behavior definition*

First of all, animal behavior is defined as "the study of how animals move in their environment, how they interact socially, how they learn about their environment, and how an animal might achieve a cognitive understanding of its environment" (Breed & Moore, 2022). The understanding of animal behavior is pertinent to making decisions on animal care and handling, which promotes the improvement of animal welfare as well. Of particular significance, when there is a clear understanding of the dam (cow) and the calf's behavior immediately after calving, the dairy operations would be able to adapt and recognize the advantages or challenges for either, the cow-calf early separation system or the cow-calf prolonged separation system.

2.2. Health performance

Turning now to the study approach available for the most relevant health performance for the cow and the calf including the prevalence (number of cases within the herd) and incidence (new cases) of digestive, and respiratory diseases, the immune response of the neonate, the weight gain for the calf and the incidence of mastitis in the Dam.

2.2.1 Health performance of the calf

Regarding the calf's health status, studies focused on Diarrhea and Bovine Respiratory disease (BRD), the most common and economically important diseases in calves (Autio et al., 2007). Thus, previous studies have found that there may be benefits to the digestive health of the calf when allowing cow-calf contact, meaning that the incidence of scours tends to be lower compared to the early separation system of less than 1 day (Nocek et al., 1984; Rajala & Castrén, 1995; Wagenaar et al., 2011; Weary & Chua, 2000).

By contrast, Quigley et al (1994) found that calves allowed to nurse (prolonged contact) had a higher weekly prevalence of Giardia and Cryptosporidium infection, the most common enteric protozoan parasites causing diarrhea in calves (Hailu et al., 2020). Likewise, studies have demonstrated that when removing the calf from the calving area or by minimizing cow-calf contact, there is a decreased likelihood of Cryptosporidium (Faubert & Litvinsky, 2000; Quigley et al., 1994; Svensson et al., 2003; Trotz-Williams et al., 2007), a parasite agent causing diarrhea. The same is the decreased likelihood effect for Mycobacterium avium ssp Paratuberculosis (Muskens et al., 2003; Patterson et al., 2020) a parasite agent that causes Johne's disease, an inflammatory disorder of the intestines (Fecteau et al., 2010) which causes chronic diarrhea. However, these studies have emphasized that beyond the contact allowance time, the results are stronger associated with the hygiene and cleaning state of the maternity pen. Additionally, it was observed that there is no significant difference in the incidence of digestive disease between early and prolonged separation (Franklin et al., 2003; Krohn et al., 1999).

With regard to the respiratory health of the calves in early cow-calf contact systems, more specifically bovine respiratory diseases (BRD) prevalence within the herd, some of the literature points out that there is no significant difference compared to prolonged cow-calf contact systems (Krohn et al., 1999; Perez et al., 1990; Svensson et al., 2003) given that there was no difference on mortality rates nor clinical respiratory disease. In contrast, Boonbrahm et al (2004) found that bucket-rearing calves have an increased morbidity rate against suckling-allowed calves

(Boonbrahm et al., 2004). Though, a study demonstrated that calves in presence of cows have an increased risk of respiratory diseases compared with calves who are housed separately immediately after calving (Gulliksen et al., 2009).

Another significant aspect of calf health when contrasting early and prolonged cow-calf contact is calf immunity, including the immunoglobulin absorption, the bacterial contamination of colostrum, and the Failure of Passive Transfer (FPT). As known calves are born agammaglobulinemic, so the transfer of maternal protective immunoglobulins (Ig) and the absorption of immune cells, cytokines, and nutritional elements, after birth, from colostrum, will determine the health and survival of the calf (Godden et al., 2019; McGuirk & Collins, 2004). Prior research has shown that the calves nursed by her Dam may acquire higher immunoglobulin concentrations, and more rapid absorption of Ig (Gulliksen et al., 2009; Petrie, 1984; Quigley et al., 1994; Stott et al., 1981; Weary & Chua, 2000), but the cause is not found to be from a higher concentration of Ig in the gland and teat cistern of the Dam (Stott et al., 1981).

These above results may indicate an advantage in the immunity performance of the calf for the cow-calf contact system, however, the failure of passive transfer (FPT) is greater when calves are allowed to suckle the cow (Besser et al., 1991; Brignole & Stott, 1980; Quigley et al., 1995). Also, there is a delayed average time to ingest the first colostrum from calves left with their mother (Besser et al., 1991; Rajala & Castrén, 1995b; Svensson et al., 2003). Hence, a successful colostrum management program implemented on-site and assisted feeding program plays a significant role in the immunity performance where rather than the contact allowed, the quality, quantity, quickness, cleanliness, and evaluation of the colostrum must drive the effectiveness of the immune passive transfer together with lower calf mortality rates in the dairy operation (Beaver et al., 2019).

In terms of calf weight gain, either no difference or greater weight gain was found between early cow-calf separation systems and prolonged contact. On one side, no difference was observed (Krohn et al., 1999; Nocek et al., 1984) and on the other side, there was demonstrated that calves in suckling systems (contact) had the potential to grow faster per day and greater average daily gain (Boonbrahm et al., 2004; Franklin et al., 2003; Krohn et al., 1999; Quigley et al., 1995; Wagenaar et al., 2011). Thus, the literature reviewed suggests that prolonged contact benefits the calf for overall weight gain.

2.2.2 Health performance of the Dam

As far as the Dam health status is concerned, most studies have relied on the incidence and prevalence of mastitis, and her milk production performance (milk yield). No difference was found in Somatic Cells Count (SCC) between suckled and non-suckled dams (Johnsen et al., 2016; Wagenaar et al., 2011), where increased udder SCC is strongly associated with an indication of mastitis (Frössling et al., 2017). Other studies also found that suckling resulted in increased udder health due to decreased incidence of mastitis (Johnsen et al., 2016; Krohn, 2001), and reduced somatic cell count (Margerison et al., 2002). In terms of the production performance (milk yield) of the Dam, the literature reviewed also reported, either increase (Fröberg et al., 2011), a decrease, or no difference (Weary & Chua, 2000) in milk yield over the long term.

2.3 Animal behavior post parturition

2.3.1 Calf behavior implications

Then, this section presents a review of recent literature on behavioral patterns resulting from both contact systems. A prominent systematic review analyzed 53 eligible studies on the effects of prolonged cow-calf contact on cow and calf behavior (Meagher et al., 2019). They categorized the main implications of acute separation behavior, social behavior, abnormal behavior, later response to stress, and other behaviors. First, the behavior patterns in the calf showed that prolonged cow-calf contact increased social interaction, either dominant, submissive, or neutral interaction. It was found that there was a decreased abnormal oral behavior such as cross-sucking, non-nutritive sucking, and tongue rolling, faster stand-up, reduced lying time, lower vocalizations in the first hour of life, and lower self-licking behavior. However, no significant difference was found in the response to potential stressors for the prolonged cow-calf system due to the diverse results in the studies reviewed.

For the sucking behavior of the calf, the mother-fed calves are shown to take longer times to suckle milk compared to bottle-fed or machine-fed calves, which has been associated with reduced non-nutritive sucking or cross-sucking (Meagher et al., 2019; Roth et al., 2009). However, studies found that prolonged mother-fed calves get a lower energy intake which may result in decreased locomotion play with a lower frequency of jumping, kicking, and bucking, and an increased frequency of vocalization (Rushen et al., 2016; Wagner et al., 2012). Calves also spend less time lying down during the first 6 hours after birth, but the number of lying bouts decreases after this time. In social behavior, a calf with prolonged separation is likely to be submissive more often compared to early separated calves(Jensen, 2012; Schnaider et al., 2022).

2.3.2 Dam behavior implications

Behaviors related to the Dam showed that she tends to smell more, move her tail, head, and body at a higher frequency, and has an increased pitch with longer vocal calls. Likewise, the cow lies down and eats less during the first hours after calving. Decreased resting time post-parturition is shown to affect the future production health of the cow (Schnaider et al., 2022). Cows have more frequent vocalizations as well (Jensen, 2012; Schnaider et al., 2022). Behavioral patterns after separation of prolonged cow-calf contact on the cow side have been associated with more frequent vocalizations in 4 studies reviewed, corroborated by Lidfors (1996).

2.4 Implications for future research

Furthermore, the latest studies in dairy animal behavior have introduced the concept of Cow-Calf Contact (CCC) systems which have increasingly drawn the interest of different stakeholders. In this system, the dairy cow stays in contact with their calves for a prolonged period which could be full or partial physical contact (Wenker et al., 2021). Thus, the full contact system allows the cow to live together with the calf for up to 5 weeks while the partial contact allows contact just for a specific number of hours per day. Those studies have explored affiliate behaviors such as lying, standing, feeding, allogrooming, nursing, and other activities done by the Dam (Wenker et al., 2021).

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CHAPTER 2: EMPLOYEE ADAPTATION, PERCEPTION, AND UNDERSTANDING OF TECHNOLOGY IN THE DAIRY FARM

Summary

The research project presented in this chapter aims to assess how farm employees perceive and understand technologies, and to identify challenges that farm employees face when adapting to technologies in dairy operations. A total of 266 farm employees participated in the online survey and a frequency distribution analysis was developed to illustrate their demographic, use, and perception of technologies. Overall, most of the respondents were identified as male (72%), Hispanic (92%), with ages between 21 to 30 years (39%), and 41 to 50 years old (37%), with a bachelor's degree (34.6%) or completed high school (29%), and they perceived to have a basic or no level of English (74%). Additionally, the majority of respondents use a personal smartphone (93%) and recognize the use of technologies in their daily routine (88%).

For the perception and understanding of technologies, more than 90 percent of employees determined to feel comfortable when using technology (96%) and new technology (90%), to feel comfortable when explaining to a colleague (90%), to understand the technology and its benefits (92%), they recognize the technology helps them to be more efficient (94%), and to have a positive attitude when a new technology is implemented (92%). Only about 80 percent of the respondents agreed to perceive the data from the technology as reliable (84%), to feel confident with the information (89%), and to receive training (80%). Lastly, 95 percent of the employees agree with their desire to learn more about new technologies. Then, the challenges identified by farm employees when adapting to technologies were not knowing the language of the technology as the main personal limitation (31%), followed by their impairment to see (24%). For the environmental limitations, cold weather was determined to be the most challenging (64%), shadowed by the wind

(45%), and when is too dark (31%), or too bright (21%). To explore the technology opportunities, first, dairy employees have a common understanding of current and innovative technologies by recognizing tablets, lasers, robots, and new machinery as tools that would be beneficial for their daily routine. Secondly, positive emotions were associated with their perception of technology such as happiness, effectiveness, comfortability, confidence, trust, and satisfaction. Also, dairy employees recognize their experience, training, concentration, responsibility, communication, and familiarity with new technologies as personal skills that help them to adapt to new technologies.

A chi-squared test of association and a logistic cumulative regression were tested to represent the significant level of association between the perception of technologies and the age, gender, level of education, and level of English of the respondents. In general, the perception of being able to easily set up or back up the technology if it's not working was negatively associated with the level of English (OR<1; $P = 0.03$). The level of English of the employee was positively associated with the perception of receiving training when there is a new technology in their work (Native OR: 6.29; P=0.0005). Employee perception to learn more about technologies at work was strongly associated with the level of education (Elementary OR: 1.55; Middle School OR: 1.21; P<0.0001), also the use of technology or the information from the technology to make decisions in their job was negatively associated with the level of English (Intermediate English OR: 0.403; P=0.03). And the recognition of someone else using the information from the technology provided by the dairy employee was negatively associated with the dairy employee's level of education (Advanced English OR: 0.163; P=0.01).

Introduction

Precision Livestock Farming (PLF) technology adoption in agricultural businesses has rapidly increased in the last decade around the world, with a growth of about 35.4 times (average) in the investment of new technologies from 2012 to 2022, with a significant growth of 107.8% in 2020 compared to 2019 (Agfunder, 2022). Overall, the United States has led this investment trend, followed by China, India, Germany, and the United Kingdom (2022). The dairy industry has followed the same tendency, with over 1 billion US$ invested from 60 companies, focusing mainly on farm management, feeding, health, and data integration software (IFCN, 2022). A few examples provided in the IFCN 2022 annual report are DairyOffice, CattleScan, LEMNA, moonset, and COWOW for companies that impact less than 100,000 cows. Also, for medium operations with an impact of between 100,000 cows and 1,000,000 cows, there are All+Hooves, MooCall, Peacock technology, UniDairy, and FarmTrace. And larger companies such as Afimilk, GEA, DeLaval, LELY, and FutureCow are applicated to more than 1,000,000 cows worldwide (2022).

Thus, PLF technology is not a new concept in the dairy industry, there has been an extensive review of the adoption of technologies in dairy farm operations. In the United States, the main systems adopted have been capital-intensive and management-intensive technologies, influenced by the size of the operation and whether the farm is located in or out of a traditional milk-producing state (El-Osta & Morehart, 2000). Farms with more than 258 milking cows are less likely to adopt a capital-intensive technology, and farms with at least 129 milking cows are more likely to invest in management-intensive technologies (2000). To maintain profitability, farms operating in traditional milk-producing states are able to adopt technologies for recordkeeping and advanced milking parlors, compared to dairy systems in non-traditional states, which focus on systems that lower expenditures in forage production, purchased feed, hired labor, and per-cow investment (El-Osta & Johnson, 1998). Also, the United States dairy farms have experienced a significant shift in operation where there are larger operations in average size but fewer farms, from 155,339 farms in 1992 to 54,599 in 2017 dairy operations (MacDonald et al., 2020). Likewise, PLF technology and automatization have performed a significant role in this shift, where producers have seen milk efficiency improvement (higher percentage of milk production per farm) due to the benefits of milking three times daily, delivering food automatized, performing milking computerized systems, and developing Artificial Insemination (AI) reproduction protocols (2020).

Other benefits have been associated with the use of technology in the dairy farm, which thrives in the viability and competitiveness of numerous dairy operations. Producers have experienced improved productivity, lower per-unit costs (El-Osta & Morehart, 2000), improved labor efficiency (Hogan et al., 2022), a significant animal welfare framework that recognizes a better reproductive and productive animal performance and which minimizes the environmental impact of the dairy operation (Barkema et al., 2015; Tullo et al., 2019). Additionally, PLF technology has been shown to help mitigate the effect of labor shortage in the industry (Charlton & Kostandini, 2021). Therefore, the implementation of PLF technology has indicated an integral approach to the enhancement of economic, environmental, and social sustainability (Lovarelli et al., 2019) with timely, informed, and improved decision-making (Jago et al., 2013) in dairy operations in the United States.

Overall, the adoption of PLF technology has brought significant benefits to the industry. However, it has led to the challenge of managing resources in the modern dairy farm, specifically to consequent implications for human resource management. Where farmers have pointed out the difficulty to find suitably skilled workers to operate in these systems (Jago et al., 2013). Thus, the success of the technology adoption and diffusion relies mostly on the system interaction together with the individual farm characteristics (Shang, L. et al 2020). In this way, personnel need to be properly trained to adapt and understand the new system, management must identify the best way to analyze the data resulting from the technologies and translate it into on-time decision-making strategies, and there must be constant communication with the manufacturer to ease technology adaptation.

A major current focus in the dairy personnel adoption, perception, and understanding of technologies needs to be addressed. The approach we have used in this study aims to describe this gap in information. Specifically, the current research aims (1) to assess how to farm employees perceive and understand technologies implemented in dairy operations, and (2) to identify possible challenges that farm employees face when adapting to technologies in dairy operations.

Materials and methods

The study of employee adaptation, perception, and understanding of technology in the dairy farm was a pilot study conducted from September 2022 to December 2022, and it was approved by Colorado State University Institutional Review Board or IRB (Protocol #3459). An online survey was distributed among the dairy operation employees with a mixed research model, including quantitative and qualitative questions. Below is a description of the experimental design, the employee characteristics, the management of the dairy farm, and the general procedures and data obtained in the research.

Experimental design

This study was descriptive research that used an online survey distributed through SurveyMonkey (SurveyMonkey Inc., Palo Alto, CA), provided to the dairy employee in English and Spanish. To protect the anonymity of this study, no respondent identifiers were used and the online survey information was shared among the private social media of the company with a QR code flier linked to the online survey. The QR code directed the employee to the online survey with a consent letter. Dairy farm employees within the operation were identified as the target audience with the following conditions specified to be eligible: participants must work at the dairy and must be over 21 years old.

Moreover, a researcher was scheduled on-site for helping sessions for three months, if participants needed help completing the online survey. The help sessions were limited to delivering the study consent, explaining the research purpose, and reading the survey in case the participant required it. Researchers were certified with CITI Human Research Behavior certification for the development of the online survey. Due to the limited review of the employee adaptation, perception, and understanding of technology in the dairy farm, the researchers created a questionnaire that aims to obtain descriptive information aligned with the study objectives.

Participant population description

The survey was completely voluntary by 277 employees at the dairy farm, including animal specialists (veterinarians, animal caretakers, milkers), agricultural resources employees (pasture management specialist, machinery, and equipment employees related to dairy operations), and any management team in the dairy such as general manager and areas supervisors (dairy, maternity, dry cows, calf yield, maintenance). However, 11 participants' responses were deleted from the study because of not following the eligibility criteria, of respondents being less than 21 years old.

Management, operation size, and technology

The study is pilot research done on three different farms within the same dairy operation, two of the farms are located in northern Colorado, and another farm is in northern Texas. The three dairies have approximately 355 employees in total at the moment of the research. All farms are managed under the same human resources guidelines and adopt almost the same technologies, however, there were few differences in the inventory technology for each farm, either by brand or quantity of technologies adopted. A described inventory of technology per farm is shown in Table 2.1. Overall, the dairy business has a total of 30.400 headcounts, including lactating cows, maternity and dry cows, heifers, and calves. The biggest dairy by headcount is located in northern Colorado with 15.300 animal headcount, followed by the dairy in northern Texas with 13.600 animal headcount and lastly the other dairy in Colorado with 1.500 animal headcount.

General procedures and methods

All respondents were protected by confidential consent. Data from the survey was imported into Microsoft Office Excel 2011, Microsoft, Redmond, WA. And shared exclusively among the research team in a closed folder created in CSU Institutional One Drive.

Respondents were asked to voluntarily complete the online survey with two main sections; the first one was a demographic questionnaire that aimed to determine significant variables about age, gender, ethnicity, level of education, main language, perceived main language domain, perceived English domain, use of the smartphone, and department within the dairy operation. Secondly, respondents were asked to complete a technology-specific questionnaire related to technologies they use in the dairy operation. This section had three main categories; first, a technology context category aims to provide information about the knowledge and understanding of the current technologies used in the farm. A Likert scale was used for the perception of technologies category, in which the participant needed to indicate their agreement scale (5- Strongly Agree, 4- Agree, 3- Neutral, 2- Disagree, 1- Strongly Disagree, 0- Does not Apply) for statements related to technology they use the most at work. Lastly, opportunities for technology adaptation category, with multiple choice and open questions that intended to learn more about the opportunities inside the dairy operation for technologies.

Statistical Analysis

Statistical analyses were conducted on all 266 surveys using SAS Version 9.4 (SAS Institute Inc., Cary, NC, USA) and Microsoft Office Word 2011 (Microsoft, Redmond, WA, USA) to analyze the qualitative (open questions) data. Frequency distribution analyses were used to represent the number of observations for demographic, use of technology, and perception of technology questionnaire. Then, a Chi-squared test of association was performed to find significant associations between each of the 16 questions for the perception of technologies -outcome- and age, gender, level of education, and level of English as variables. Lastly, to find the predicted level of association between those variables, logistic cumulative regression (multinomial) was tested.

Results

1. *Demographic and tech-demographic description*

A demographic description of the population was obtained from the demographic questionnaire in the online survey (Table 2.2). In total, 266 employees participated in the study; 72.2 identified as male, 23.7% as female, and 4% between no-binary and no response. The higher proportion for age is between 21 to 30 years old with 39.1%, followed by employees with 31 to 40 years old, 41 to 50 years old, and more than 50 years old, with 36.8%, 13.5%, and 10.5% respectively. 246 (92.5%) employees were Hispanic or Latino (248 considered Spanish as their main language), and 13 (4.9%) respondents identified as white or Caucasian (16 considered English as their main language). The majority of respondents completed a level of education in Bachelor's (34.6%), followed by Middle school (29.3%), with a lower proportion for those who did not attend any level of education (9.02%). Lastly, below half of the participants perceived to not know any English (42%), and as many as 85 (32%) participants considered to know a basic level of English, with a few respondents knowing an intermediate (14.6%) or advanced (6.4%) level. The participants were divided by departments related to their task(s) at the dairy, 31% work at the milking parlor, 23% in animal caring, 17% in operation and maintenance, 9.4% in the calf care and/or heifer raising, 8.6% as feeders, 8.6% in animal reproduction, 6.4% of respondents as supervisor or manager, and 5.6% at the farm office.

Subsequently, participants responded to the questionnaire about technology use, as reported in Table 2.3. Most of the dairy employees indicated using a personal smartphone daily (248 out of 266). Further to the use of technology in their job, 88.3% of respondents recognize the use of technology in their daily routines with 86% of participants who use it every job day, and 5% 2 to 3 times per week. From the technology they use, the higher proportion of the technology used is for cow milk production and the health status of the animal, recognizing DeLaval milking parlor and LELY robot milking parlor, CASE/ John Deere/ KUBOTA machinery, PocketDairy (DRMS), and the OneWand. Other cow health status software is identified such as CowManager, CowAlert. LELY collars and IceQube pedometers.

2. *Perception and understanding of technologies description.*

The results from the perception and understanding of technologies questionnaire show a significant proportion of agreement among the dairy employees in this research (Table 2.4). 95.6% of dairy employees agree to feel comfortable when using technology in their daily routine, they feel comfortable explaining to a colleague how the technology works (90.3%), they agree to understand the technology (91.7%) and its benefits (92.1%), respondents agree to recognize technology helps them to be more efficient (93.7%), they agree that the data from the technology is reliable (84.1%) and feel confident with the information from the technology (89%). From the resources the dairy must provide for the use of the technology, 80.2% of dairy employees agree to recognize those and agree to receive the training when using new technology (83.4%). A meaningful agreement was found in their comfortability when a new technology is implemented (90.3%), and they agree to have a positive attitude when adapting to new technologies (92.4%). Still, the level of agreement to set up or back up the technology when is not working is divided into neutral and disagreement perceptions (48.5%). Overall, 95% of dairy employees agree significantly in their perception to want to learn more about new technologies at the dairy farm.

3. *Opportunities to adapt to technologies description.*

As outlined in the introduction, the aim of this study is to identify possible challenges that farm employees face when adapting to PLF technology in dairy operations. Therefore, the opportunities to adapt to current and new technologies were specified in two main areas, a set of limitations that might constrain the effective use of the technology, and a category that seeks to explore those opportunities through personal emotions, feelings, skills, and perception of benefits from new technologies, as shown in Table 2.5. First, dairy employees recognized not knowing the language of the technology as the main personal limitation (31%), followed by impairments in their sight (24%), light sensibility (14%), and not knowing how to read (7%). Then, respondents strongly agreed with the cold weather as the biggest environmental limitation (64.3%), as many as 46% agreed to consider the wind as an environmental limitation, 31% when is too dark, 21% when is too bright, 18% the hot weather, and others who responded rain (3%) and snow (2%) as external limitations for the technology use.

Secondly, to explore the technology opportunities, employees were asked "Which technology do you think will be beneficial for your work?", They had an open question where they could type the answer. Thus, from the word cloud illustrated in Figure 1.1, there is a common understanding of current and innovative technologies by the dairy employees, they agreed to recognize tablets, lasers, robots, and new machinery as tools that will be beneficial for their daily routines, mainly in the milking parlor, maintenance, cow heat detection, temperature control and data integration from different technologies. Employees were most likely to cite how they would like to have more robots ("robots for milking cows", "robots that help us to push the cows to the milking parlor, "robots that sort the cows themselves", "robot that detects lame cows or cows with diseases", "robot to apply iodine", "more robot barns"), followed by maintenance tools and machinery ("program that monitors the maintenance of vehicles, "good maintenance accessories on hand", "tools in general for maintenance", "more courses or videos to learn more in the maintenance field"). Also, the live upload of data from tablets was significantly mentioned by the dairy employees ("internet in the workplace to sync the tablet", "all information is uploaded automatically without the need to sync tablets", "implement a technology that could connect to tablet and sync immediately, especially for the weekends").

Dairy employees were also asked to list 3 emotions or feelings in "How the technology makes them feel?", and to list 3 skills they consider to help them understand the technology at work. Overall, their feelings and emotions towards technology, illustrated in Figure 1.2, were positive with a strong agreement in feeling happy, effective, good, comfortable, confident, trustworthy, efficient, satisfied, peaceful, productive, excellent, practical, and safe. And a few negative emotions such as feeling stressed, uncomfortable, frustrated, and tired. Moreover, the personal skills they recognized the most that help them to adapt to new technologies were experience, training, practice, concentration, responsibility, communication, and their previous knowledge of personal technologies like smartphones, tablets, and computers (illustrated in Figure 1.3).

4. *Association between perception and understanding of technology with gender, age, level of education and level of English.*

The chi-square test for a potential association between the perception and understanding of the technology questionnaire and the gender, age, level of education, and level of English is summarized in Table 2.6. Overall, many associations were found between the level of English and level of education, however, there was no significant difference between the perception and understanding of technology with gender and as few as one difference with age (*P-value* greater than 0.05). Age was associated with the setup or backup ability, while the level of education was differentiated by setup or backup ability, the recognition of the efficiency and benefits of the technology, its external use, and the desire to learn more about technologies. Additionally, the level of English was associated with the setup or backup ability, the perception of using the technology as a tool to make decisions, to be more efficient, their positive attitude towards technology, and the recognition of technology training.

In more detail, the employee perception about being able to easily set up or backup the technology if it's not working was associated with age (*P*=0.03), level of education (*P* =0.004), and level of English (*P* = 0.03). The perception of technology helping the employee to be more efficient in their daily operations was associated with the employee's level of education (*P*=0.04), also the use of technology or the information from the technology to make decisions in their job was associated with the level of English (*P*=0.03). The understanding of the benefits of the technology that the employee uses was associated with the level of education (*P*=0.02) and level of English (*P*=0.04). The positive attitude of the dairy employee when adapting to new technologies was associated with the level of English (*P*=0.02). The recognition of someone else using the information from the technology provided by the dairy employee was associated with the dairy employee's level of education (P=0.01). The level of English of the employee was strongly associated with the perception of receiving training when there is a new technology in their work (P=0.0005). Lastly, employee perception to learn more about technologies at work was strongly associated with the level of education (P<0.0001).

5. *Level of association between the likelihood of agreement between the perception and understanding of technologies with gender, age, level of education, and level of English*

The cumulative logistic (multinomial) regression aimed to predict (Liang et al., 2020) the likelihood of agreement among the perception and understanding of technologies with gender, age, level of education, and level of English of the dairy employees. Overall, gender was not found significant in the likelihood of agreement test for all questions about the perception and understanding of technology (data not shown). Whereas age was found to be a significant factor that varies the level of likelihood agreement when dairy employees use the technology or the information from the technology to make decisions in their job. Therefore, participants from 21 to 30 years old are predicted to have 3.34 higher odds (95% CI 1.4, 8,1) to agree to use the technology to make decisions in their job, compared to employees more than 50 years old (see Table 2.7).

Moreover, the English level was a predictive factor for a few perceptions and understanding of technology statements. A summary of the estimated coefficients and odds ratio for this association is shown in Table 2.8. So, employees with intermediate, advanced, or native levels of English are less likely to agree to easy setup or back the technology if it is not working (OR: 0.41, 0.21, 0.28 respectively). Likewise, dairy employees with an intermediate level of English are 0.4 odds less likely to use technology to make decisions in their job. An advanced level of English employee is 0.16 odds less likely to recognize that the information they enter the technology someone else uses. But Native English speaker employees are 6.3 odds times (95% CI: 1.9, 21.2) more likely to recognize they get training when there is a new technology in their work.

The level of education of the dairy employee was positively associated with the likelihood of agreement, summarized in Table 2.9, to feel comfortable explaining the technology, recognizing the resources provided by the dairy, and the desire to learn more about new technologies, against the reference of no attending any level of education. Therefore, the dairy employee who completed a technician certificate was 6.2 odds times (95% CI 1.2, 30.4) more likely to agree to feel comfortable explaining the technology to their colleague. The employee with a bachelor's degree was 3.03 odds times (95% CI 1.2, 7.8) more likely to agree to recognize the resources provided by the dairy for the use of the technology. And the desire to learn more about using technologies at work was likely agreed to 1.55 odds (95% CI 1.5, 28.9) more by dairy employees who completed elementary school and 1.22 higher odds (95% CI 1.2, 17.7) to agree by participants who completed middle school.

Discussion

Prior work has documented the adoption and understanding of PLF technologies among dairy producers, and dairy management overall. This study tested the extent to which dairy employees would adapt, perceive, and understand the PLF in their daily operations. Previous studies have acknowledged the demographic profile of dairy cattle employees in the United States; although most of the studies are primarily limited to health and safety assessments, and occupational medicine studies, by studying the effects of certain components exposure on the health of dairy workers, and the challenges in health and safety training at the workplace. In this pilot study, we aimed to describe the demographic of the dairy employees to then test if age, gender, level of education, and level of English might be associated with the perception and understanding of technologies in the dairy farm.

In accordance with previous findings, the demographic profile of the current pilot dairy employee is almost similar to those reported in previous work documented, with more than 70% of dairy employees identified as male (Martenies et al., 2020; Menger, Pezzutti, et al., 2016; Rosecrance et al., 2013), a significant proportion of Latino immigrants and Spanish-speaking dairy workers (Eastman et al., 2013; Menger, Pezzutti, et al., 2016; Menger, Rosecrance, et al., 2016; Schenker & Gunderson, 2013). Though, the age range of this study was demonstrated to be slightly younger compared to the dairy industry, with a mode of 21 to 30 years old, opposite to the industry average of 34 years old (Mitchell et al., 2015). In addition, the level of education differed from the dairy industry with a significant number of employees who completed a Bachelor's degree (34.6%) and Middle school (29.3%), compared to 57% of dairy workers who completed up to Elementary school (Eastman et al., 2013; Mitchell et al., 2015).

The current study did not find any significant association between employees' gender and the perception and understanding of technologies, these results are similar to those reported by a study done in Canada (n_1=26.935 dairy operators) which aimed to describe the adoption of 8 specific technologies by the Canadian dairy industry (Jelinski et al., 2020). These results contrast with that of Groher et al., (2020), where male respondents from Swiss ruminant operations were most likely to adopt technologies, compared to female respondents. Differences across studies may be due to the low proportion of female respondents in the current research (n=63/266), relative to the Canadian study (n=505/ 26.935), and the Swiss study (n=34/ 832). Additionally, dairy employees' age was only significant for the perception of being more likely to use technology to make decisions in their job for respondents between 21 to 30 years old. Although, studies have shown the inverse correlation between the adoption of technology and age, where older dairy farmers are less likely to adopt new technologies within the operation (Groher et al., 2020; Hill et al., 2015; Shang et al., 2021).

However, some limitations are worth nothing. Although the previous and current studies aimed to determine farmer characteristics like age, gender, level of education, and level of English as predictors for the perception and understanding of technologies, the respondents were targeted differently. In the current pilot study, the dairy employee was targeted, and in the majority of the studies discussed, the principal target was the dairy operator and/or owner, who might have different interests and variables to consider when implementing new technology. Thus, the dairy employee has to adapt to a technology the owner decides to adopt, so the perceptions within these two groups may significantly differ. The owner/operator has to consider the economical pillar of investment cost, the return on investment (ROI), maintenance, and other related costs when perceiving a PLF technology, in addition to the social and environmental pillar (Lovarelli et al., 2020). While the dairy employee determines the likelihood of perception as a result of the technology use and common previous understanding.

The following part of this thesis moves on to describe in greater detail how the results from the perception and understanding of technologies likelihood among this pilot study with dairy employees, can be compared to previous work done in the adaption to PLF technologies in the dairy industry. As mentioned above, the perceptions among dairy farmers (either the employee or owner/producer) might have limitations due to the specific targeted population among studies. Thus, prior research has thrived to analyze the comfortability and understanding of the perception of technology in the dairy industry and the implication of technology training. So, the current results showed that only 2.34% of the respondents feel uncomfortable when using technology in their daily routine, 1.56% did not understand how the technology works, and 16.6% consider they do not receive training when there is a new technology. Whereas Drewry (2019) found a significant level of lack of comfort with technologies (54.5%), a major level of lack of understanding (51.4%) as well, and considered a notable proportion in the lack of technology training (45.4%) as barriers that inhibit the technology adoption(Drewry et al., 2019).

There are some important limitations to note when interpreting the results of this study. First, this was a pilot study developed within the same business, where the three farms are managed under the same Human Resources and operational procedures, but on average they count with the same proportion of dairy technologies in each operation. Second, as discussed above, the analysis of the results compared to previous studies has to include the difference in the targeted population, the dairy employees compared to the dairy owner/ producer perception. Although, the purpose of the current research is to describe the employee adaptation, perception, and understanding of technologies in the dairy farm, is important to note that this type of research has not been extensively reviewed (to the author's knowledge), so the comparison interpretation was determined to be with studies that included the dairy farmer overall.

Third, the respondents were asked to determine their level of perception, for example, their level of English/ Spanish, their skills when using technology at work, and their ability perception to set up the technology. Thus, these types of questions could be regulated by the unrealistic self-enhancement of the respondent, which has been used to refer to situations in which people rate their abilities as better than "average" (Kim et al., 2017). Lastly, and beyond a limitation, the demographic profile of the current study is similar to the one in the dairy industry among gender, ethnicity, and level of English, with a slightly younger average age and advanced level of education.

Despite these limitations, the current study has significant findings, the results are encouraging and should be validated in a larger cohort of dairy employees. The pilot study has shown consistency in the demographic profile among the dairy industry in the United States, with a minor age difference and level of education contrast. In summary, the current study has shown that native English speakers highly recognize the training provided for adapting to new technology, compared to no level of English. Also, completing a bachelor's was associated with a greater likelihood of recognizing the resources provided by the operation to use the technology, and elementary and middle schoolers highly recognized the desire to learn more about technologies at work. Lastly, 21 to 30 years old age was positively associated with the likelihood of using technology as a tool to make decisions, compared to the older population (>50 years old). The inclusion of demographic description would be beneficial for further research, to determine similarities or contrast with the adaptation, perception, and understanding level of technology among dairy employees.

Additionally, the identification of opportunities to adapt to technologies for dairy employees should be replicated, by recognizing dairy employees' emotions, skills, and personal and environmental limitations when using technologies. The current research identified significant barriers described by dairy employees when using technologies, such as cold weather, high wind, not knowing the system's main language, and eye limitations. Also, results showed that dairy employees associated positive emotions and feelings with the use of technology at work, and employees recognize the practice, experience, and previous knowledge as personal skills that help them understand the technology. By identifying these variables, future studies should therefore include work designed to evaluate how the technology limitations could be addressed, for example, an association study that hypotheses that previous technology training in the employee's main language would improve the level of understanding of PLF in their daily routine. Likewise, an opportunity to improve technologies should be explored by manufacturers, to offer a user-friendly system with a shared language among the dairy industry as a result of the communication across stakeholders. Thus, with further research (academia) and constant communication with dairy operations, the manufacturers would be able to better understand their end-user, the employee.

Conclusion

Dairy employees in the current pilot study perceive PLF technology as a tool they understand, they recognize its benefits, and recognize the resources provided by the dairy management for its use. Dairy employees also perceived the data from the technology as a reliable source of information, that they can use to make decisions. The likelihood of agreement in perception and understanding of technologies were mostly associated with the dairy employee's education level and English level. However, there are still opportunities to adapt to technologies for dairy employees that can be estimated by recognizing their emotions, skills, and personal characteristics. Likewise, by determining the environmental limitations dairy employees might face when using technologies in the dairy operation.

The current study has been one of the first attempts to thoroughly examine the employee adaptation, perception, and understanding of technology in the dairy farm, and invites to extend its validation to a larger cohort of dairy, and livestock operations overall. Results showed that dairy employees stated their desire to learn more about PLF technologies implemented at work, which could eventually lead to improved efficiency at the dairy operation due to shared language and higher motivation from their workforce. Moreover, an implication of this will be the possibility that academia can benefit from more reliable data for future research due to a language shared by all the employees in the farm operation. Thus, the findings are promising and should be explored in all livestock operations, the framework provided can help guide future research on the adaptation, perception, and understanding of technology by the farm employee. Which in turn will be a valuable input for technology manufacturers in updating and developing new PLF technologies.

Table 2.1. Dairy farm inventory of technology per farm (3 farms) within the same business.

Technology inventory in the dairy (company)	Dairy[1]	Head Count[2]
Calf feeder (LELY)	NC1	1,500
Collars (LELY)	NC1	1,500
CowAlert (Peacock Technology)	NC2, NT	28,900
CowManager (CowManager)	NC1	1,500
IceQube pedometers (ICEqube)	NC2, NT	28,900
Milk pasteurizer (Perfect Udder)	All	30,400
Milking parlor (DeLaval)	All	30,400
Milking Parlor (LELY)	NC1	1,500
One Wand	All	30,400
PCDart Software (DRMS)	All	30,400
Pivots water management	All	30,400
PocketDairy (DRMS)	All	30,400
Robot Feed pusher	All	30,400
Swinging cow brush (DeLaval)	All	30,400
TMR Tracker Software (Topcon)	All	30,400
Tractor/ loader CHASE/ John Deere/ Kubota machinery	All	30,400
Sorting gate	All	30,400

[1] The dairy farms were categorized as NC1-Northern Colorado 1; NC2- Northern Colorado 2; and NT- Northern Texas.
[2] Total head count.

Table 2.2. Responses from employees (n=266) in 3 dairy farms within the same operation to the demographic questionnaire including gender, age, ethnicity, level of education, and level of English.

Demographic Variables[1]	**Response (n)**	**Response (%)**
Gender		
Female	63	23.7
Male	192	72.2
Prefer not to answer	8	3.01
No-binary	3	1.1
Age		
21 to 30 years old	104	39.1
31 to 40 years old	98	36.8
41 to 50 years old	36	13.5
Over 50 years old	28	10.5
Ethnicity		
Asian or Pacific Islander	3	1.1
Hispanic or Latino	246	92.5
Native American or Alaskan Native	2	0.7
White or Caucasian	13	4.9
Ethnicity not described	2	0.7
Level of Education		
None	24	9.02
Elementary School	27	10.1
Middle school	78	29.3
Highschool	23	8.6
Technician	9	3.4
Bachelor	92	34.6
Master's degree or above	9	3.4
Other	4	1.5
Primary language		
English	16	6.02
Spanish	248	93.2
Other	2	0.7
Level of English (perceived)		
None	112	42
Basic	85	32
Intermediate	39	14.6
Advanced	17	6.4
Native	13	5
Dairy operation department[2]		
Animal caring	62	23
Animal reproduction	23	8.6

Calf/ heifer raising	25	9.4
Farm office and administration	15	5.6
Feeder	23	8.6
Milking parlor	82	31
Operator/ Maintenance	45	17
Supervisor/ Manager	17	6.4

[1] Responses were attained anonymously from the online survey.

[2] Frequency response over the total sample (n=266). Self-reported by dairy employee. In many cases, they cited more than 1 primary department.

Table 2.3. Responses from employees (n=266) in 3 dairy farms within the same operation to the tech-demographic questionnaire included personal smartphone use, technology use in the dairy operation, and technology inventory used.

Tech-Demographic Variables	**Response (n)**	**Response (%)**
Personal use of smartphone		
Yes	248	93.2
No	18	6.7
Use of technology in dairy operation		
Yes	235	88.3
No	31	11.6
Frequency of technology use in dairy operation		
Every day	229	86
2 to 3 times per week	13	4.9
4 to 5 times per week	9	3.4
Once per month	5	1.9
Twice per month	1	0.4
N/A	9	3.4
Technology inventory in the dairy (company)[1]		
Calf feeder (LELY)	15	5.6
Collars (LELY)	12	4.5[3]
CowAlert (Peacock Technology)	28	10.5
CowManager (CowManager)	31	11.6
IceQube pedometers (ICEqube)	31	11.6
Milk pasteurizer (Perfect Udder)	32	12.03
Milking parlor (DeLaval)	101	37.1
Milking Parlor (LELY)	18	6.7
One Wand	54	20.3
PCDart Software (DRMS)	40	15.04
Pivots water management	18	6.7
PocketDairy (DRMS)	81	30.4
Robot Feed pusher	44	16.5
Swinging cow brush (DeLaval)	12	4.5[3]
TMR Tracker Software (Topcon)	31	11.6
Tractor/ loader CHASE/ John Deere/ Kubota machinery	112	42.1[2]
Sorting gate	34	12.8

[1] Frequency response over the total sample (n=266). Self-reported by dairy employee. In many cases, they cited more than 1 primary technology used.
[2] Indicates highest proportion for technology used.
[3] Indicates lowest proportion for technology used.

Table 2.4. Likert responses frequency from employees (n=266) in 3 dairy farms within the same operation to the perception and understanding of technologies questionnaire.

Perception and Understanding of technology Question[1]	5		4		3		2		1	
	n (%)		n (%)		n (%)		n (%)		n (%)	
1. I feel comfortable using technology in my daily routine.	159	(61.8)	87	(33.8)	5	(1.9)	3	(1.2)	3	(1.2)
2. I understand how technology works.	136	(53.1)	99	(38.6)	17	(6.6)	3	(1.2)	1	(0.4)
3. I can easily set up or back up the technology if it is not working.	46	(19.4)	76	(32.07)	60	(25.3)	32	(13.5)	23	(9.7)
4. I feel comfortable with the language in the technology I am using.	116	(45.7)	94	(37.01)	30	(11.8)	12	(4.7)	2	(0.8)
5. I feel comfortable explaining to my colleague how to use the system.	125	(48.4)	108	(41.9)	21	(8.1)	3	(1.2)	1	(0.4)
6. Technology helps me to be more efficient in my daily operations.	168	(64.8)	75	(28.9)	13	(5.02)	2	(0.7)	1	(0.4)
7. I understand the benefits of the technology that I am using.	149	(58.2)	87	(33.9)	17	(6.6)	2	(0.8)	1	(0.4)
8. I recognize that the information I enter in the system, someone else is using it.	114	(50.0)	82	(35.9)	26	(11.4)	3	(1.3)	3	(1.3)
9. I feel confident using the information from the technology that I am using.	129	(50.8)	97	(38.2)	22	(8.6)	4	(1.6)	2	(0.8)
10. I use technology or the information from the technology to make decisions in my job.	111	(46.06)	91	(37.7)	29	(12.03)	7	(2.9)	3	(1.2)
11. The dairy provide me with all the resources I need to use the technology.	114	(44.2)	93	(36.05)	39	(15.1)	10	(3.8)	2	(0.8)
12. The data resulting from monitoring systems are reliable.	99	(40.4)	107	(43.7)	33	(13.5)	5	(2.04)	1	(0.4)
13. I feel comfortable using new technology when implemented at my work.	120	(46.3)	114	(44.02)	18	(6.9)	6	(2.3)	1	(0.4)
14. I get training when there is new technology in my work.	114	(44.02)	102	(39.4)	26	(10.04)	13	(5.02)	4	(1.5)
15. I have a positive attitude when adapting to new technology at my work.	154	(58.8)	88	(33.6)	20	(7.6)	0	-	0	-
16. I would like to learn more about using technologies at work.	182	(69.2)	68	(25.8)	10	(3.8)	1	(0.4)	2	(0.7)

[1] Likert scale questions from survey: scale 5 to 0; 5- strongly agree response, 4- agree, 3- neutral, 2- disagree and 1-strongly disagree response; score 0- Does not apply responses were excluded from the frequency analyses.

Table 2.5. Responses from employees (n=266) in 3 dairy farms within the same operation to the opportunities to adapt to technologies questionnaire.

Opportunities to adapt variable[1]	**Frequency (n)**	**Frequency (%)**
Personal Limitations to Technologies		
Eye problems (nearsightedness, shortsightedness)	63	24
Light Sensibility	37	14
Not know how to read	18	7
Not know the main language of the technology	83	31
Environmental limitations to technologies		
Extreme cold weather (below 20F)	171	64.3
Extreme hot weather	48	18
When is too dark	83	31.2
When is too bright	56	21.05
Wind	122	46
Other: Snow[2]	5	2
Other: Rain[2]	7	3

[1] Frequency response over the total sample (n=266). Respondents had multiple choice option with the limitations they consider when using technologies at the dairy operation.
[2] The *Other* variable was an open question category responded by survey participants.

Table 2.6. Chi-square test of association between the perception and understanding of technologies questionnaire with variables such as gender, age, level of education, and level of English.

Outcome: perception and understanding of technology question	*P-value*			
	Gender	Age	Level of education	Level of English
1. I feel comfortable using technology in my daily routine.	0.88	0.87	0.05	0.84
2. I understand how technology works.	0.84	0.53	0.36	0.501
3. I can easily set up or back up the technology if it is not working.	0.19	0.03*	0.004**	0.03*
4. I feel comfortable with the language in the technology I am using.	0.9	0.34	0.6	0.14
5. I feel comfortable explaining to my colleague how to use the system.	0.80	0.83	0.35	0.97
6. Technology helps me to be more efficient in my daily operations.	0.63	0.48	0.04*	0.05
7. I understand the benefits of the technology that I am using.	0.79	0.39	0.02*	0.04*
8. I recognize that the information I enter in the system, someone else is using it.	0.99	0.31	0.01*	0.23
9. I feel confident using the information from the technology that I am using.	0.95	0.69	0.29	0.99
10. I use technology or the information from the technology to make decisions in my job.	0.97	0.04	0.21	0.03*
11. The dairy provide me with all the resources I need to use the technology.	0.78	0.74	0.05	0.32
12. The data resulting from monitoring systems are reliable.	0.92	0.92	0.93	0.92
13. I feel comfortable using new technology when implemented at my work.	0.88	0.03	0.56	0.89
14. I get training when there is new technology in my work.	0.94	0.84	0.27	0.0005**
15. I have a positive attitude when adapting to new technology at my work.	0.88	0.18	0.102	0.02*
16. I would like to learn more about using technologies at work.	0.36	0.91	<0.0001***	0.09

Asterisks indicate levels of significance: $*P \leq 0.10$; $**P \leq 0.05$; $***P \leq 0.01$.

Table 2.7. Estimated coefficients and odd ratios from a cumulative logistic multinomial regression for the association between level of education and Likert question 10[1]. (n=266)

Age	OR[2]	95% CI	*P-value*
21 to 30 years old	3.34	(1.4, 8.1)	0.008**
31 to 40 years old	1.33	(0.5, 3.3)	0.54
41 to 50 years old	1.44	(0.5, 4.1)	0.49

[1]Question 10, "I use technology or the information from the technology to make decisions in my job."

[2]Odds ratio for perception and understanding of technology agreement, calculated at a reference value of older than 50 years.

Asterisks indicate levels of significance: *$P \leq 0.10$; **$P \leq 0.05$; ***$P \leq 0.01$.

Table 2.8. Estimated coefficients and odd ratios from a cumulative logistic multinomial regression for the association between level of English and Likert questions 3, 8, 10, and 14. (n=266)

Variable	Level of English			
	Basic	Intermediate	Advanced	Native
Question 3[1]				
OR[5]	0.86	0.41	0.21	0.28
95% CI	0.4, 1.6	0.2, 0.9	0.07, 0.6	0.09, 0.8
P-value	0.64	0.03*	0.003**	0.02*
Question 8[2]				
OR[5]	0.52	0.49	0.16	0.29
95% CI	0.3, 1.02	0.2, 1.2	0.03, 0.7	0.07, 1.1
P-value	0.05	0.11	0.02*	0.07
Question 10[3]				
OR[5]	0.88	0.4	0.61	0.84
95% CI	0.4, 1.7	0.2, 0.9	0.2, 1.9	0.2, 2.9
P-value	0.69	0.04*	0.41	0.78
Question 14[4]				
OR[5]	1.39	1.99	1.1	6.3
95% CI	0.7, 2.6	0.9, 4.5	0.4, 3.5	1.9, 21.2
P-value	0.29	0.09	0.81	0.003**

[1] Question 3, “I can easily set up or backup the technology if it is not working",

[2] Question 8, “I recognize that the information I enter in the system, someone else is using it”.

[3] Question 10, “I use technology or the information from the technology to make decisions in my job.” And

[4] Question 14, “I get training when there is a new technology in my work."

[5] Odds ratio for perception and understanding of technology agreement, calculated at a reference value of none level of English for categorical variables.

Asterisks indicate levels of significance: *$P \leq 0.10$; **$P \leq 0.05$; ***$P \leq 0.01$.

Table 2.9. Estimated coefficients and odd ratios from a cumulative logistic multinomial regression for the association between level of education and Likert question 5, 11, and 16. (n=266)

Variable	Level of education					
	Elementary	Middle	Highschool	Technician	Bachelor	Graduate
Question 5[1]						
OR[4]	1.04	2.54	2.44	6.2	2.22	4.1
95% CI	0.3, 3.4	0.9, 6.8	0.70, 8.4	1.2, 30.4	0.8, 6.2	0.8, 19.9
P-value	0.94	0.06	0.16	0.025*	0.12	0.08
Question 11[2]						
OR[4]	0.77	1.05	2.97	1.95	3.03	0.88
95% CI	0.2, 2.4	0.4, 2.6	0.9, 9.5	0.4, 9.07	1.2, 7.8	0.2, 4.8
P-value	0.644	0.92	0.068	0.395	0.022*	0.888
Question 16[3]						
OR[4]	1.55	1.22	0.37	0.38	0.68	0.82
95% CI	1.5, 28.9	1.2, 17.7	0.4, 10.2	0.4, 25.2	0.7, 11.03	0.8, 40.8
P-value	0.0108*	0.024*	0.43	0.29	0.15	0.07

[1]Question 5, "I feel comfortable explaining to my colleague how to use the system.",
[2]Question 11, “The dairy provides me with all the resources I need to use the technology.”.
[3]Question 16, “I would like to learn more about using technologies at work.”
[4]Odds ratio for perception and understanding of technology agreement, calculated at a reference value of none level of education for categorical variables.
Asterisks indicate levels of significance: *$P \leq 0.10$; **$P \leq 0.05$; ***$P \leq 0.01$.

Figure 2.1. Word Cloud responses from employees (n=266) in 3 dairy farms within the same operation to the opportunities to adapt question, "Which technology do you think will be beneficial for your work?"

Figure 2.2. Word Cloud responses from employees (n=266) in 3 dairy farms within the same operation to the opportunities to adapt the question, "In three words, describe how the technology implemented at work makes you feel?"

Figure 2.3. Word Cloud responses from employees (n=266) in 3 dairy farms within the same operation to the opportunities to adapt the question, "Mention three skills you consider that help you understand the technology at work"

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CHAPTER 3: COW-CALF BEHAVIOR FROM THE EXPULSION OF THE CALF UP TO SEPARATION IN A DAIRY SYSTEM

Summary

The current study aimed to (1) describe the early interaction between the dam and the calf up to the separation, (2) analyze the behavioral patterns of the dam and the calf after calving, (3) analyze the relationship between pre-calving variables (days in maternity, parity, weather conditions at calving) and Dam Calf Behavior (DCB), and (4) evaluate the association between DCB and dam-calf health performance up to 14 days after calving. Overall, 167 calving were recorded, and the average contact of the dam with its calf was 2,489 seconds (SD= 1,836 ss, Min: 60ss, Max: 9,180ss), 8.38% of the calving needed assistance, 33% of dams calved alone and 15% calved in the patio. The main behavior expressed by the dam was intense licking for 1,155 seconds after calving and moderate licking for 1,803 seconds after calving. Other relevant behaviors expressed by the dam were lying down (27.5%), aggressive behavior upon surrogate presence (11.8%), and from 70 dams that were taken first upon separation, less than half followed her calf (65.8%). Then, the main behaviors expressed by the calf were licking the cow (12.6%), mobilizing with their two front hooves (79.6%), standing up (37.7%), walking (30.5%), reaching the udder behavior (18.6%), and suckling (3.6%). Upon separation of 70 calves taken first, only 15% looked at their cow.

For the third objective, parity (primiparous vs. multiparous) of the dam was associated with aggressive behavior of the dam towards its calf (P=0.02), and toward other cows (P=0.06). The sucking intent behavior of the calf was associated with dam parity as well (P=0.003). Dystocic births were only associated with the dam following and looking at her calf upon separation

(*P*=0.08, P=0.06), and the stand-up intent of the calf (*P*=0.003). Calf gender (Female vs. Male) was associated with the licking behavior of the calf towards its cow (*P*=0.05). For the environmental variables, the drop time (AM/PM) was found to have a significant association with the aggressive behavior of the dam (*P*=0.06), the licking behavior of the calf (*P*=0.001), the suckling behavior of the calf (*P*=0.023), and the stand-up intent of the calf (*P*=0.008). Lastly, the lowest temperature on the day of birth was associated with the avoidance behavior of the dam (*P*=0.03), and aggressive behavior of the dam (*P*=0.06). Lastly, no significant association was found between dystocia, twin presence, calving in the patio, and heat index with dam or calf licking, sucking behavior, and stand-up intent of the calf.

To accomplish the last objective, the most significant finding was that about 32% of dams presented a health condition up to 14 days after birth, and as few as 6.9% of the calves showed a health condition up to 14 days after birth. Also, calves that stood up during the time together with their cow had an increased average daily gain weight from birth to weaning compared to calves that did not (ADG: 1.78 lbs./day; 1.47 lbs./day, respectively). Also, a calf that liked a cow right after birth is estimated to have an ADG (on average) of 2.04 lbs./day, compared to an ADG of 1.52 ls/day for a calf that did not lick a cow (P=0.02).

Introduction

Significant challenges have arisen for dairy operations regarding the management of the cow and calf immediately after calving. There is a dilemma in implementing early separation or prolonged cow-calf contact, which has resulted in a benchmarking of benefits and improvement opportunities for both systems. The increased focus on both systems among academia, producers, consumers, and other stakeholders has highlighted the need to conduct research on behavioral patterns, welfare states, and the performance of the animals. This need is also a response to ethical concerns in animal science that drives regulation and legislation (Barnard, 2007). The social structure demonstrated by consumers is included in this ethical dilemma. The consumers emphasize the urgent need to learn and understand the process behind an animal-based operation. This learning process is led by the ability consumers have to access and share information about products, and the challenge for companies to keep positively engaged with them (Renner & Ringquist, n.d.)

Thus, producers gain a valuable advantage once they can demonstrate to the public view a sustainable production that aligns animal welfare, employee well-being, and environmental responsibility. However, when introducing the animal welfare conversation in cow-calf management immediately after calving, often exposes conflicting interests concerning opponents and supporters for either, an early cow-calf separation system or a prolonged contact system (Ventura, B, et al, 2013). Areas, where significant differences have been found, include the economic viability for the producer, the ethical preference of both producer and consumer (Beaver et al., 2019), emotional states of the cow such as frustration and satisfaction (Sandem & Braastad, 2005), the health performance of the cow and the calf (Meagher et al., 2019), and the short and long term effects on behavior (Flower & Weary, 2001b; Meagher et al., 2019).

There remains a need for the development of efficient methodology for experimental studies, presented by Daiana de Oliveira (2020), that describes the cow behavior before and during calving, the early behavior of the calf, the post-partum behavior of the dam, the social behavior, the human-animal behavior, and the separation behavior for both the cow and the calf. Also, that research reflection encourages researchers to include performance parameters such as milk yield, weaning, and health status indicators (2020). Thus, much research in recent years has focused on the cow and the calf behavior of the early cow-calf separation system, prolonged cow-calf separation system, and most recently the partial cow-calf contact (CCC) system. However, although some implications of these systems were found over the last 30 years, little attention has been paid to the natural maternal behavior of the cow and the calf's early behavior from birth to early separation, and its association with its immediate health status. The approach we have used in this study aims to describe these relations. Specifically, the current research aims (1) to describe the early behavior between the dam and the calf up to the separation, (2) to analyze the behavioral patterns of the dam and the calf after calving, (3) to analyze the relation between pre-calving variables (days in maternity, parity, weather conditions at calving) and DCB, and (4) to evaluate the association between dam calf behavior (DCB) and dam-calf health performance up to 14 days after calving.

Materials and Methods

This study was conducted from May 25 to June 29, 2022, and it was approved by the Colorado State University Institutional Animal Care and Use Committee or IACUC (Protocol no.3499). This study followed the exempt waiver because it did not require any treatment or intervention of the animals. The main goal of this study was to describe the behavior between the dam and the calf from calving up to separation, by analyzing behavioral patterns. And then, evaluate the association between those behaviors with cow and calf future health performance. Therefore, below is a description of the experimental design, the farm, the animals, the management of the maternity pen, and the general procedures and measures implemented in the research.

Experimental design

This study was an observational study that aimed to describe the behavior of the cow and its neonate(s). Two researchers video-recorded the behavior of each calving with two GoPro cameras, and one CANON camera at regular speed from the moment the calf was dropped by her cow until the cow or the calf was taken by the dairy caretaker. Thus, the drop of the calf refers to when the Dam finishes its second stage of parturition, the abdominal contractions, and expulsion of the fetus. Researchers had previous training to recognize when a cow was close to calving so they could be in the area the cow was calving and then start video recording. Researchers kept a distance from the cow greater than 6 feet to avoid disturbing the calving. A record in paper of the cow index, cow tag color, time for calf drop, and separation time was also taken at the time of calving. For each video recording, the researchers said the cow index out loud to then associate the video with the cow. All cow-calf behaviors were analyzed from the video recording. The after-separation procedure followed the dairy protocols explained below.

Farm, animals, and management

One-hundred sixty-three primiparous and multiparous cows that calved from May 25th to June 29, 2022, were used in this behavioral study, including 5 of these cows that had twins. A total of 1330 calvings happened during this period; however, researchers could only video-recorded 167 calvings (12.5%) because those happened when they were present at the dairy from Monday to Friday in different periods of time, from 7 am to 5 pm. And, there were calving that happened simultaneously, but the research team had just 3 different cameras to video-record at the same time. Cows were predominantly Holstein from a single certified organic dairy farm located in Northern Colorado, USA. The average lactation number for all the cows was 2.8 (range 1 to 9). Pregnant cows are moved to the maternity pen ±10 days prior to the estimated calving date and are housed in free-stall barns with access to a dry lot patio. All pregnant cows are commingled in the pen with no difference in days due or parity. Water was provided at libitum, and they were fed a Total Mixed Ration (TMR) two times daily to meet their nutritional requirements. The diet was based on corn silage (10.5 to 16% DM basis), wheat silage (10.5 to 16.6%), alfalfa hay (32 to 41%), grain mix (12.6 to 19.2%), and mineral and vitamin mix (3.8%). The cows calved unassisted unless it was required, as determined by the dairy protocol, and the dairy caretakers walked the pen every hour to check normal timing during calving. If assistance was required, the dairy assistance protocol was performed by farm employees. The protocol for assistance was not shared with the research team because the study did not include the intervention of the researchers in the calving.

Separation occurred when either the neonate was taken or the dam was led to the line maternity chute, following farm protocols. The caretakers carefully take the calf to its pen to provide it with its nutritional requirement of colostrum and take the dam to the maternity chute to check her. Employees at maternity check the cow for the possible presence of another calf, milked her to get the colostrum, and applied the vaccination and sanitation protocol. The time between calf drop and separation was, on average, 40.8 minutes, ranging from 2 minutes to 2 hours and 32 minutes.

The protocols for calving assistance, post-partum treatment of the cow and calf, and employee training in maternity were not necessary for this research because the research aims to describe early behavior in a natural environment, where the research team did not need knowledge about it.

General procedures and measures

All video recordings for each cow were saved on an external safe hard drive approved by the IRB and then analyzed for different behaviors, shown in Table 3.1. A researcher watched the 167 videos and recorded the data described in Table 3.1., using Microsoft Excel Office, Microsoft, Redmond, WA. Then, general data for the cow and the calf, and the health status performance of the dam and the calf were collected from farm records, shown in Table 3.2. Other external variables were included in the study such as temperature, and heat index, also provided by farm records. All the timing for behavior was considered in seconds for better analysis. These data were added to the Microsoft Excel spreadsheet created for Table 3.1 and Table 3.2.

Statistical Analyses

For analyses purpose, the time together between the dam and the calf was determined as quantiles; the first quantile was a time less than 960 seconds (16 minutes), the next quantile was a time between 960 and 1,860 seconds (16 to 31 minutes), then a time between 1,860 and 3,540 seconds (31to 59 minutes), and the last quantile was a time greater than 3,540 seconds (59 minutes). An exploratory analysis was performed first to describe the frequencies and statistical summaries of dam and calf behaviors right after calving. Then, a chi-squared was tested to determine the association significance of animal behaviors, compared to animal and environmental observations during calving. Likewise, an ANOVA was tested for the continuous variables in the current study such as licking times, sucking behavior of the calf time, and standup of the calf time.

Results

The animal behaviors (binary variables) included in this test during contact were licking from dam to calf, nursing, avoidance behavior from the dam to the calf, aggressive behavior from the dam to the calf, from the dam to another cow, and from the dam to the presence of a surrogate. Also, submissive behavior from the dam to the presence of a surrogate cow. On the calf side, variables included were the licking from calf to dam, and from calf to another cow, the sucking behavior from the calf to the dam, and behavioral observation of the calf wanting to reach the udder (sucking behavior). The stand-up intent from the calf was added as well. From the herd interactions, the presence of another cow as a surrogate cow at calving and after (up to 5 min after) was also considered, meaning that another cow was licking or having maternal behavior with the calf. Lastly, during separation, the behaviors included were if the dam followed and/or looked at the calf, and if the calf looked at the dam.

Animal and environmental observations were included in the association to determine significant predictors of those behaviors such as parity (primiparous vs. multiparous), dystocia, if the dam had twins, the calf gender, if the dam gave birth at the maternity dry lot patio, the drop time (AM vs. PM), a high or low temperature, and the heat index for the calving date.

Descriptive analyses

Summary statistical analysis was used to describe the early behavior between the dam and the calf from calving up to separation, refer to objective 1. As mentioned above, the average time that the dam spent with her calf was 2,489.1 seconds (SD= 1,836 ss, Min: 60ss, Max: 9,180ss). The specific average time for each quantile is described in Table 3.3.

1. *Calving description*

Of the 167 calvings recorded, 14 needed assistance (dystocia) of which 10 dams were kept with her calf for less than 960 seconds, 3 were kept with her calf between 960 and 1,860 seconds, and 1 dam was kept with her calf between 1,860 and 3,540 seconds. Also, from the 167 calvings, 56 of the dams (33.5%) calved alone, meaning no other cows were around and 25 of cow calved in the patio (14.9%), illustrated in Table 3.4.

2. *Dam behaviors from expulsion of the calf to separation*

Overall, 162 dams licked the calf (n=167) and they started licking in an average of 87 seconds after the neonate expulsion, shown in Table 3.3. The time when the dam stopped licking the calf for 30 seconds (intense), up to 2 minutes (moderate), up to 5 minutes (low), and stopped completely was also recorded. Thus, on average the cow had an intense licking until 1,155 seconds after the expulsion of the calf, a moderate licking of 1,803 seconds after the expulsion, a low licking after 2,437 seconds, and a stopped licking on average of 2,259 seconds after the expulsion of the calf.

After the calving, 10 of the dams showed avoidance behavior with her calf by leaving or separating from where the calf was. Also, three dams showed aggressive behavior with her calf and eighteen dams showed aggressive behavior with another cow right after calving. Then, upon the presence of a surrogate cow the whole time the dam was with her calf, 19 dams showed aggressive behavior and 18 showed submissive behavior with the surrogate. The greater proportion of aggressive dams was in Q3 and Q4 (68.4%) when the dam spends more than 1,860 seconds with her calf. Moreover, 46 of the dams lie down 1704.08 seconds after calving. Lastly, 97 of the dams were taken first to check her according to farm protocols, and during the separation, 43.7% of the dams followed her calf and 65.8% kept looking at her calf. All these behaviors are illustrated in Table 3.4.

3. *Calf behaviors from birth up to separation*

Behaviors of the calf right after birth were recorded such as licking behavior, sucking behavior, stand-up and walk time, socialization, and following behavior towards its cow, shown in Table 3.5. Thus, 18 of the neonates licked her dam (10.7%) and 21 licked also another cow (12.6%). Also, 133 calves stood in their two front hooves, on average, 510 seconds (SD=458 ss) after birth, then, stood also with their rear hooves approximately 1,186 seconds after (SD=927ss) after its expulsion, 63 calves stood up, on average, 1,789 (SD=1,288) seconds after birth and only 51 walked 1,949 seconds (SD= 1297 ss) after. In addition, the calf behavior to reach the udder was included as well as the sucking achievement, 31 calves tried to reach the udder approximately 6,260 seconds (SD=20,460) after birth, and only six calves had a successful udder suckling, on average, 2,191 seconds after birth. However, a description accounting for the time together is shown in Table 3.5. Lastly, 70 calves were separated first and just 15% showed a looking behavior towards their cow.

Association between the Dam or Calf behavior after calving up to separation, compared to animal and environmental observations.

To find significant predictors of the dam or calf behavior, refer to objective 2, a chi-square test of association was used to analyze the significance of the association between the behavioral patterns of the dam and the calf right after calving. Overall, significant associations between the aggressive behavior of the dam, licking behavior in both, sucking behavior of the calf, and stand-up intent of the calf were found with the dam parity (primiparous vs. multiparous), calving difficulty (dystocia), calving in the patio and the drop time (AM vs. PM), as summarized in Table 3.6. Therefore, from the animal observation, the parity of the dam was associated with the aggressive behavior between the dam and the calf (P=0.02), the aggressive and submissive behavior of the dam with the cows around (P=0.06 and P=0.06, respectively), a strong association with licking behavior of the calf with another cow (P=<0.0001), and the sucking behavior of the calf to its dam (P=0.003). Secondly, the dam that needed assistance (dystocia) was associated with the behavior of the dam following the calf (P=0.09), the dam looking at the calf (P=0.013), the sucking behavior of the calf to its cow (P=0.06), and the stand-up intent of the calf before separation (P=0.003). Third, if the dam had twins was only associated with the standup intent of the calf (P=0.04). Lastly, the calf gender (Female or Male) was associated with the licking behavior between the calf to its cow (P=0.04).

In the environmental observation side, the drop time was found to have a significant association with the aggressive behavior from the dam to the calf (P=0.06), a strong significance with the licking behavior from the calf to its cow (*P*=0.001), and significant associations with the sucking behavior of the calf to its dam (*P*=0.02), the stand-up intent of the calf (*P*=0.008), and the looking behavior from the calf to their cow (*P*=0.02). Then, the highest and lowest temperature of the calving date was correlated with the avoidance behavior from the dam to its calf (*P*=0.06 and *P*=0.03, respectively). The lowest temperature was also associated with the aggressive behavior of the dam with the other cows (*P*=0.06), and the aggressive behavior with the surrogate cow (*P*=0.09). Finally, the looking behavior from the calf to its cow at separation was associated with the heat index of the calving date (*P*=0.09).

Likewise, an ANOVA test was used to analyze the estimated time and significance of the association between the behavioral patterns of the dam and the calf right after calving and up to separation, the significant values are illustrated in Table 3.6. Thus, a primiparous dam is expected to stop licking the calf for 30 seconds, on average, 881 seconds (14.7 min) after calving, compared to a multiparous dam on average spending 1,196 seconds (20 min), accounting for the time together (*P*=0.09). Likewise, a primiparous dam is expected to stop licking the calf for more than 5 minutes, on average, 3,923 seconds (65 minutes) after calving, compared to a multiparous cow average spending 2,272 seconds (37 minutes), accounting for the time together (*P*=0.002).

Additionally, the highest temperature on the day of birth was associated with licking behavior, first, when the highest temperature is between 85 to 97 F, the dam is expected to stop licking the calf for 30 seconds, on average, 979 seconds after its expulsion compared to a temperature between 97 to 106F where the dam stopped licking 1,450 seconds after birth (*P*=0.02). Then, when the highest temperature is over 106F, the calf is expected to lick another cow 2,051 seconds after calving, compared to a temperature between 85 to 97F where the calf starts licking another cow 1,594 seconds after birth (*P*=0.09). Also, when the highest temperature is between 85 to 97F, the calf is expected to lick another cow an average of 1,594 seconds after calving, compared to start licking another cow 31362 seconds after with a high temperature of 97 to 106F (*P*=0.04).

However, no evidence was found for significant linear associations between dystocia, twin presence, calf gender, calving in the patio, drop time, low temperature, and heat index compared to dam or calf licking behavior, sucking behavior, and stand-up intent of the calf. Despite of significant value for dystocia, and twins (*P*<0.0001), there was not a significant sample of dystocic births and twins to compare.

Logistic Regression for linear associations for Dam-Calf behaviors right after calving

A multivariable generalized linear mixed model was tested for objective 3, summarized in Table 3.8, to analyze the association between whether the dam had dystocia, whether the dam was primiparous or multiparous, calved in the patio or inside, dropping the calf in the morning or afternoon, compared to the individual-level behaviors of an aggressive dam, avoidance behavior of the dam, licking behaviors, sucking behavior of the calf, standup behavior of the calf, and following or looking behavior upon separation. Thus, the current pilot study found that, overall, primiparous dams had increased odds ratio of occurrence for these behaviors, as well as, if the dam calved inside the barn and in the afternoon, compared to calving in the patio or in the morning. A dam with dystocia had decreased odds ratios of looking and following the calf upon separation. Lastly, the behavior of the dam avoiding the calf had increased odds ratios during a day with the highest temperature of more than 106F.

1. Dystocia

Accounting for time together, dams with eutocic calving had an increased odds ratio, compared to dystocic calving dams, to look at her calf upon separation (OR=3.9 ,95%CI: 1.2, 13.1). Also, the behavior of following among eutocic dams had an increased odds ratio towards her calf, compared to dystocic dams (OR=6.7, 95%CI: 0.7, 58.2). Though, this interaction was not significant.

2. Primiparous vs. Multiparous dams

For the same time together and calving area (patio nor barn), multiparous dams in this model had decreased odds ratios, compared to primiparous dams, to have a calf that licked another cow (0R=0.102, 95%CI: 0.03,0.3), and to have a calf that showed a sucking behavior after calving (OR=0.17, 95%CI: 0.05, 0.5). Multiparous cows had an estimated average time to stop licking their calf for more than 5 minutes after 2,272 seconds, compared to primiparous cows that on average stopped licking their calf for more than 5 minutes at 3,923 seconds later (P=0.002). Also, multiparous dams had decreased odds ratio, compared to primiparous dams, to be aggressive with their calf (OR=0.08, 95%CI:0.007, 1.03) for the same time together, with another cow (OR=0.34, 95%CI: 0.1,1.1) for the same time together, calving area, and calving company. Accounting for time together, and time of birth, multiparous dams had decreased odds ratio of having a calf that stands up (OR=0.402, 95%CI: 0.15, 1.9). However, the interaction between these three last factors was not significant (confidence Interval included 1).

3. Calving patio

Moreover, accounting for time together and parity, dams that calved inside had decreased odds ratios (compared to the dam that calved in the patio) to be aggressive with another cow (OR=0.17, 95% CI: 0.05, 0.5), to be aggressive upon a surrogate presence (OR=0.17, 95% CI: 0.05,0.6), to had a calf that licked another cow (OR=0.3, 95%CI: 0.09, 0.99). Also, dams calving inside were more likely to have a calf that looked at her at separation (OR= 0.16, 95%CI: 0.06, 0.4), and to have a calf that showed a sucking behavior (OR=0.08, 95%CI: 0.01,0.5) for the same time together and birth time (AM or PM). When the interaction had the same time together and the same lowest temperature, dams calving inside were more likely to avoid her calf (OR=0.19, 95%CI: 0.04,0.9). In addition, dams that calved in the patio had increased odds ratio to count with the presence of a surrogate at calving, compared to the dam that calved inside (OR=2.5, P=0.05, 95%CI: 0.9,6.6) for the same birth time and time together. However, this last interaction was not significant.

4. Drop time and temperature.

Afternoon calving had an increased odds ratio, compared to morning calving, to have a calf that licks its cow (OR=5.103, 95%CI: 1.4, 18.9), considering the time together. Other interactions were not significant; however, it is important to consider such as the sucking behavior of the calf had an increased odds ratio of occurrence during the afternoon compared to the morning calving (OR=3.48, 95%CI: 0.3, 33.2). The same was for the standup intent, where calves born in the afternoon were more likely to stand up (OR=1.7, 95%CI: 0.8,3.8). Lastly, the behavior of the dam avoiding the calf had increased odds ratios during a day with the highest temperature of more than 106F, compared to a temperature between 97F to 106F (OR=4.03, 95%CI:1.005, 16.2), for cows that calved in the same area and spent the same time with her calf.

Future performance of the dam and the calf

The health performance of the dam and the calf was tracked up to fourteen days after the calf's birth. To evaluate the association between DCB and the dam and calf health performance, refer to objective 4, a chi-square test of association and ANOVA test were established, the results are shown in Table 3.9. Overall, fifty-three dams presented on average one or two health conditions and four left the herd in this time frame. Only four out of the fifty-eight calves kept (included in this pilot study) had at least one health condition up to 14 days after birth, and no calves left the herd. Therefore, a chi-square test of association was performed to determine the significance between animal-level behavior and the health performance of both animals. From the results, the licking behavior from the calf to its cow was associated with the health of the dam (*P*=0.04), and the avoidance behavior of the dam towards her calf was associated with the dam leaving the herd (*P*=0.04). On the other side, the aggressive behavior of the cow with another cow and upon the presence of a surrogate was associated with the health status of the calf (*P*=0.04). Likewise, the presence of a surrogate cow during calving was significatively associated with the calf leaving the herd (*P*=0.03).

Specifically, the average daily gain (ADG) of the calf was analyzed to determine any possible linear association with animal-level behaviors right after calving, summarized in Table 3.10. Hence, a calf that liked a cow right after birth is estimated to have an ADG (on average) of 2.04 lbs./day, compared to an ADG of 1.51 ls/day for a calf that did not lick a cow (*P*=0.02). Also, a calf that stood up during the time together with her cow had an estimated average ADG of 1.78 lbs./day compared to a 1.467 ADG from a calf that did not stand up (*P*=0.02). Finally, a calf from a cow that was aggressive with another cow right after calving had an expected average daily gain of 2.12 lbs./day compared to an average gain of 1.494 for calves with non-aggressive cows (*P*=0.0009).

Discussion

Prior work has documented the behavioral patterns of the dam and the calf in immediate separation and prolonged separation systems, and how it is associated with the future performance of the dam and the calf. However, these studies have either been in different management systems or focused on a few predictors such as dam parity or breed. The present study was designed to determine the immediate effect of the calf and the dam behaviors right after calving and up to separation in a dairy operation with early cow-calf contact, where separation occurred in less than

3 hours after birth. This study extends to test how dam-level variables and environmental factors at calving could be associated with the latent behaviors right after calving for the dam and the calf.

The maternal behavior in mammalian species has been highly emphasized in the licking and nursing behavior immediately after calving. Primarily, the current study found that 97% of the dams showed a predominant licking behavior to their calves. These results reflect those of (Edwards & Broom, 1982) who also found that licking the newborn is the main behavior expressed by the cow, which occupies 30% to 50% of the first hour postpartum. Also, the intensive licking behavior decreased over time when the dam stopped licking the calf for a longer period after 38 minutes, on average. Although the current study found that primiparous cows are more likely to stop intensively licking the calf sooner (14.7 minutes after birth), compared to multiparous cows (19.9 minutes after birth), other studies have not found a significant association between parity and licking behavior in the first hour after birth (1982). A possible explanation for this might be that licking patterns have been extensively described in maternal mammal behavior as a source of benefits for the neonate such as the development of the pain regulatory system (Sakamoto et al., 2021), systemic protection of infections (Hart & Hart, 2018), development of endocrine responses, regulation of emotional states, and reduced stress levels in the cow (Bienboire-Frosini et al., 2023). Also, it has been described as the main maternal behavior right after calving so the cow is able to learn the odor and features of the neonate for later recognition (Vaglio, 2009), and the mechanism for placentophagia (Kristal et al., 2012) which has been shown to determine the formation of the mother-infant bond.

Moreover, mammals are characterized by the subsequent behaviors of teat-seeking immediately after birth, promoted by the arousal movements of the cow that invites the neonate through senses to have contact and facilitate the location of the udder (Nowak, 2000). Thus, the current study found that just 18.56% of the calves tried to reach the udder and was more prevalent in calves from primiparous cows, and dams that calved inside. There are similarities between the reaching udder behavior expressed by calves in this study and those described by Edwards & Broom (1982), where younger dams had a higher proportion of promoting their teat seeking compared to older dams, due to the pendulous conformation of the udder in older dams that might limit this behavior, however, the frequency for interrupted suckling is shorter for older dams.

Likewise, mammals are also characterized by their mother-progeny relationship to recognize their neonate, where their maternal motivation is shown to be maximal at the birth of their young, and the main mechanism that indicates caring behavior is the proximity to lick and nurse the newborn (Poindron, 2005). Although dairy cattle also demonstrate this recognition behavior, the study found 6% of dams that showed an avoidance behavior towards their calf. Additionally, most of the studies have described the dam as an aggressive cow in the presence of humans or animal handlers, as a protective response to potential predators (Orihuela & Galina, 2021). However, the current study expanded prior work and analyzed the temperament behavior of the dam related to her calf, and other cows around after calving. Thus, only 1.8% of dams showed aggressive behavior with their neonates, and 10.8% of the dams showed aggressive behavior with other cows. Also, primiparous cows were more likely to be aggressive, in accordance with Proudfoot & Huzzey (2022), and cows that calved inside showed better temperament, compared to cows that calved in the patio.

On the calf side, the behavior found in this study supports previous research into neonate behavior which links the time together between the dam and the calf and the motion behavior of the calf. Thus, calves from this study tried to stand up, on average, 19.7 minutes after birth and stood up and walk, on average, 29.8 minutes after birth, a finding consistent with the literature, which has demonstrated that calves remain motionless for up to 30 minutes after birth and try to stand up 20 minutes after birth (Lorenz et al., 2011; Orihuela & Galina, 2021).

Upon separation and accounting that 58% of the dams were taken first, the current study did not identify different profiles in the dam and the calf behavior at separation among dam-level variables but found that dams that calved inside the barn were more likely to have a neonate that looked at their cow during separation. Only dams with eutocic calving were most likely to look at her calf during separation and dams with dystocic calving were less likely to look or follow the calf upon separation. Unlike Flower & Weary (2001a) who demonstrated that when the calf spends more time with its cow, it has an increased response rate to separation. However, the current study did not test for differences compared to prolonged cow-calf contact systems. It is difficult to explain this result, but it might be related to the non-genetic inheritance (NGI) phenomenon, described as the preparation of the offspring for an environment that was experienced in previous generations. Also, dairy cattle have been characterized by their natural hider behavior that accustoms them to periods of separation (Engmann, 2018). Then, this study analyzed behaviors for up to three hours of contact, meaning that the time together might not represent distress due to separation, compared to if there was a longer contact time.

Other significant findings in the current study related to secondary behaviors in the dam and the calf right after calving. First, the social dynamics of the calving herd at calving were surprisingly in contrast with previous findings, where the minority of the dams calved alone (33.5%), and from this only 6.59% were primiparous, compared to 27% of multiparous cows that calved alone. This is significantly different from previous studies that determine the isolation-seeking behavior as a main characteristic of dairy cattle and even more predominant in primiparous cows (Proudfoot & Huzzey, 2022). It seems possible that these results are due to the phenomenon described by Lidfors et al. (1994), who concluded that cows might consider a suitable calving place more important than isolation from the herd, suitable meaning a dry and soft surface to lie on. Second, the data obtained in the standing behavior of the dam was consistent with the literature, where on average cows lay down after 28.40 minutes after calving, and this behavior was more latent in multiparous cows. Thus, other studies have demonstrated a decreased standing behavior over time after parturition, and a decreased lying down behavior by primiparous animals (Edwards & Broom, 1982b). Second,

Lastly, the successful health performance of the calf was associated with the behavioral pattern of standing up. Thus, a calf that stood up had an expected ADG of 0.312 lbs. per day higher, in contrast to calves that did not stand up during contact with their cow. This relationship may partly be explained by the assessment of calf vigor which indicated that the propensity to stand up after birth is an indicator of calf vitality (Campler et al., 2015). This finding is promising and should be explored and replicated with other types of animal management to validate its significance and to avoid the type I error of false-positive.

A straightforward analysis was presented which enables the accurate prediction of different dam and calf behaviors right after calving. However, the generalization of these behaviors among dairy operations remains to be determined due to difference in contact systems, immediate versus prolonged, and distinctions in management practices and strategies. Thus, an important question for future studies is to determine the associations among organizational strategies related to maternity administration such as colostrum, housing, handling, and transition period management. Therefore, by understanding the latent behaviors of the dam and the calf right after calving, future work should focus on how the difference in these management practices would determine the predominant behaviors in the animal and their future performance.

Conclusion

The aim of the present research was to describe the early behavior between the dam and the calf (DCB) up to separation, to analyze their behavioral patterns, to analyze the relation between animal-level variables and DCB, and to evaluate the DCB and dam-calf health performance up to 14 days after calving. Overall, the average time allowed that the dam spent with its calf was 41 minutes. The predominant behavior of the dam was licking the calf with an intense licking of about 20 minutes. The temperament behavior of the dam was mainly calm with less than 10% of the dams who showed aggressive behavior. And upon separation, 66% of the dams looked at the calf and less than half followed them. On the calf side, the main behavior showed was the motion performance by 79% of calves placing their front hooves 8.5 minutes after birth, intent to stand at 20 minutes after birth, 38% of calves standing up at 29 minutes after birth, and 30% of calves who walked at 32.5 minutes after birth. Then, the behavior of reaching the udder was present in 18.5% of calves after 1 hour and 44 minutes of birth.

The second major finding was the relation between animal-level and environmental variables with dam and calf behavior. Logistic regression analysis revealed that eutocic dams were more likely to look at her calf upon separation, compared to a difficult birth. Among parity, multiparous cows were expected to stop licking intensively the calf sooner, had less aggressive behavior, and were expected to have a calf that stood up less and showed less sucking behavior. Moreover, for environmental variables, dams that calved in the patio were expected to be more aggressive, to have a calf with reduced sucking behavior, and less likely to look at her cow upon separation. Also, calving in the patio was associated with an increased presence of a surrogate cow. Dams that calved in the afternoon were more likely to have a calf with latent behavior of suckling and stand-up intent. Finally, dams that calves during the highest temperature (>106F) were more likely to show an avoidance behavior towards their neonate compared to a lower temperature.

To accomplish the last objective, the most obvious finding to emerge from this study is that about 32% of dams presented a health condition up to 14 days after birth, significantly associated with the licking and avoidance behavior of the dam towards her calf, and as few as 6.9% of the calves showed a health condition up to 14 days after birth, only associated with the aggressive behavior of the cow with another cow and upon the presence of a surrogate. The research also found that calves that stood up during the time together with their cow, had an increased average daily gain weight from birth to weaning. No other reproductive and productive future performance of the animals was included due to the presence of multiple factors that could alter the variability of the results in the long term. For example, by concluding that a behavior presented after calving could be associated with higher/ lower milk yield, must include all the management strategies present during the transition period of the dam.

These findings have significant implications for the understanding of how dam and calf behave right after calving and up to separation and suggest animal-level and environmental variables that might determine certain behaviors. But the generalizability of these results is subject to certain limitations. For instance, management strategies should be considered when drawing conclusions to determine which cow-calf contact system represents better animal welfare and improved animal behavior right after calving. A natural progression of this work is to analyze how management strategies might impact the immediate behavior of the animals, for example, by controlling for variables such as parity, cows around, and the limitation to calve in the patio or inside the barn. Thus, if the debate is to be moved forward, a better understanding of management practices in the transition period needs to be developed.

Table 3.1. Observational behaviors for the Dam-Calf analyzed (n=167 calvings) in a dairy farm located in Northern Colorado.

Behaviors	Dam	Category[1]	Calf	Category[1]
Behaviors after calving	Time together	c (1,2,3,4)[2]		
	Licking Frequency: total Licking, licking within 30 seconds, 2 minutes, and 5 minutes with no licking.	n (ss)	Licking frequency to Dam and/or another cow.	n (ss)
	Nursing the calf	b (1/0)	Sucking behavior	n (ss)
	Lying down and standing; for the first time.	n (ss)	Socializing	n (ss)
			Two hooves time; 2 hooves+2 rear times; stand up time and walking time.	n (ss)
Calving environment	Dystocia or assistance needed.	b (1/0)		
	Calving alone	b (1/0)		
	Surrogate cow at calving or 5 min after.	b (1/0)		
	Submissive behavior	b (1/0)		
	Aggressive behavior	b (1/0)		
	Calving patio	b (1/0)		
Separation behavior	Following the calf	b (1/0)	Looking at the Dam	b (1/0)
	Looking at the calf	b (1/0)		

[1] Variable category; c- categorical variable measured in quantiles; n- numerical variable measured in seconds; b- binary variable measured by yes (1) or no (0).

[2] Categorical variable measured in quantiles- 1 for less than 18 minutes, 2 for 18 to 35 minutes, 3 for 35 to 61 minutes, and 4 for more than 61 minutes

Table 3.2. Performance data collected from Management Software for Dam and Calf prior calving and post-calving (n=167 calving) in a dairy farm located in Northern Colorado.

Performance	Dam	Category[1]	Calf	Category[1]
General data	Index	c	Index	c
	Breed	c	Sex	b (1/0)
	Days in milk	n(days)	Weight at birth	n(lbs.)
	Parity	c	Weight at weaning	n(lbs.)
			ADG	n(lbs.)
Health performance	Three first health remark	c	Three first health remark	c
	No. days in the hospital	n	No. days in the hospital	n
	Left the herd	b(1/0)	Left the herd	b (1/0)
	Date left the herd	n(days)	Date left the herd	n(days)
	Reason to left the herd	c	Reason to left the herd	c

[1] Variable category; c- categorical variable; n- numerical variable; b- binary variable measured by yes (1) or no (0).

Table 3.3. Summary statistics for Dam behavior timing (in seconds) right after the expulsion of the calf and up to separation in a dairy located in Northern Colorado (n=167 calving).

Dam behavior/ Quantile	n	Mean	SD	Min.	Max.
Time together DC	167	2,489	1,836	60	9,180
<960ss	39	555	243	60	960
960-1860ss	44	1,455	276	1,020	1,860
1860-3540ss	43	2,772	508	1,920	3,540
>3540ss	41	5,140	1,212	3,660	9,180
Licking DC start	162	87			
<960ss		51	96	1	500
960-1860ss		72	145	1	866
1860-3540ss		165	283	2	1,355
>3540ss		60	100	1	451
Licking DC ends	162				
<960ss		523	244	79	1,020
960-1860ss		1,342	325	453	1,830
1860-3540ss		2,525	597	542	3,593
>3540ss		4,556	1,461	60	9,120
Lying Down D	46				
<960ss		-	-	-	-
960-1860ss		989	109	862	1,124
1860-3540ss		1,688	707	526	2,977
>3540ss		1,834	883	105	3,648
Stand Up Dam	46				
<960ss		-	-	-	-
960-1860ss		1,263	185	1,050	1,472
1860-3540ss		9,051	29,299	1,164	126,420
>3540ss		2,496	930	657	4,698

D refers to the Dam, C to the calf (neonate). The upper case for the animal also indicates the direction; DC is Dam to Calf.

Table 3.4. Frequency table by quantile for Dam behaviors right after the expulsion of the calf and up to separation in a dairy located in Northern Colorado (n=167)

	Frequency					
Dam behavior[1]	Yes (n)	Yes (%)	No (n)	No (%)	N/A (n)2	N/A (%)
Nursing calf	2	1.2%	165	98.8%		0.00
<960ss	0	0.0%	39	23.4%		0.00
960-1860ss	0	0.0%	44	26.3%		0.00
1860-3540ss	1	0.6%	42	25.1%		0.00
>3540ss	1	0.6%	40	24.0%		0.00
Avoidance	10	6.0%	157	94.0%		0.00
<960ss	5	3.0%	34	20.4%		0.00
960-1860ss	1	0.6%	43	25.7%		0.00
1860-3540ss	2	1.2%	41	24.6%		0.00
>3540ss	2	1.2%	39	23.4%		0.00
Dystocia	14	8.4%	153	91.6%		0.00
<960ss	10	6.0%	29	17.4%		0.00
960-1860ss	3	1.8%	41	24.6%		0.00
1860-3540ss	1	0.6%	42	25.1%		0.00
>3540ss	0	0.0%	41	24.6%		0.00
Aggressive DC	3	1.8%	164	98.2%		0.00
<960ss	0	0.0%	39	23.4%		0.00
960-1860ss	1	0.6%	43	25.7%		0.00
1860-3540ss	0	0.0%	43	25.7%		0.00
>3540ss	2	1.2%	39	23.4%		0.00
Aggressive DCow	18	10.8%	149	89.2%		0.00
<960ss	0	0.0%	39	23.4%		0.00
960-1860ss	6	3.6%	38	22.8%		0.00
1860-3540ss	5	3.0%	38	22.8%		0.00
>3540ss	7	4.2%	34	20.4%		0.00
Calving alone	56	33.5%	111	66.5%		0.00
Calving patio	25	15.0%	142	85.0%		0.00
Aggressive D upon Surrogate	19	11.4%	99	59.3%	49	0.29
<960ss	0	0.0%	24	14.4%		0.00
960-1860ss	6	3.6%	25	15.0%		0.00
1860-3540ss	5	3.0%	28	16.8%		0.00
>3540ss	8	4.8%	22	13.2%		0.00
Submissive D upon Surrogate	18	10.8%	8	4.8%	141	0.84
<960ss	1	0.6%	1	0.6%		0.00
960-1860ss	2	1.2%	1	0.6%		0.00
1860-3540ss	8	4.8%	2	1.2%		0.00
>3540ss	7	4.2%	4	2.4%		0.00
Dam separated first	97	58.1%	70	41.9%		0.00

<960ss	17	10.2%	22	13.2%		0.00
960-1860ss	25	15.0%	19	11.4%		0.00
1860-3540ss	30	18.0%	13	7.8%		0.00
>3540ss	25	15.0%	16	9.6%		0.00
Following DC	73	43.7%	87	52.1%	7	0.04
Looking DC	110	65.9%	57	34.1%		0.00

[1] Categorical variable measured in quantiles- Q1 for less than 18 minutes, Q2 for 18 to 35 minutes, Q3 for 35 to 61 minutes, and Q4 for more than 61 minutes.
2 frequency of N/A is because there was not an opportunity to express the behavior.
D refers to the Dam, C to the calf (neonate), and Cow to another cow in the herd (no the cow). The Upper case for the animal also indicates the direction; DC is Dam to Calf, CD is Calf to Dam, DCow is Dam to another cow, and Ccow is Calf to another Cow.

Table 3.5. Frequency table by quantile for Calf behaviors right after birth and up to separation in a dairy located in Northern Colorado (n=167).

	Frequency[2]		Summary Statistics (time)[3]	
Calf behavior[1]	Yes	No	Mean (ss)	SD. (ss)
Licking CD	18	149	n/a	n/a
Licking CCow	21	146	n/a	n/a
Sucking CD behavior start	31	135	6,261	20,460
<960ss			-	-
960-1860ss			1,047	340
1860-3540ss			12,531	35,033
>3540ss			3,298	1,377
Sucking CD start	6	161		
<960ss			-	-
960-1860ss			1,488	-
1860-3540ss			2,024	380
>3540ss			2,537	1,212
Socializing start	25	142	6,416	21857.68
<960ss				
960-1860ss			1,066	281
1860-3540ss			12,810	35,353
>3540ss			2,872	1,378
Two hooves start	133	34	510	458
<960ss	16	22	400	185
960-1860ss	39	5	384	267
1860-3540ss	37	6	623	645
>3540ss	41	0	570	448
Two hooves+ 2rear start			1,186	927
<960ss			335	294
960-1860ss			701	390
1860-3540ss			1,164	823
>3540ss			1,530	1,095
Stand up start	63	104	1,789	1,288
<960ss	0	38	-	-
960-1860ss	12	31	922	401.47
1860-3540ss	20	22	1,478	809.06
>3540ss	31	10	2,335	1520.551
Walk start	51	115	1,949	1297.495
<960ss	0	38	-	-
960-1860ss	7	37	796	346
1860-3540ss	18	25	1,554	585
>3540ss	26	15	2,533	1,505
Looking CD	25	142	n/a	n/a

[1]Categorical variable measured in quantiles- Q1 for less than 18 minutes, Q2 for 18 to 35 minutes, Q3 for 35 to 61 minutes, and Q4 for more than 61 minutes.

[2] Frequency for binary behaviors Yes (1) or No (0).
[3] Summary statistics for continous variables on the time the behavior started (seconds), n/a apply for just binary variables.
D refers to the Dam, C to the calf (neonate), and Cow to another cow in the herd (no the cow). The Upper case for the animal also indicates the direction; DC is Dam to Calf, CD is Calf to Dam, DCow is Dam to another cow, and Ccow is Calf to another Cow.

Table 3.6. Chi-square test of association between the Dam (D) or Calf (C) behavior after calving up to separation, compared to animal and environmental observations in a maternity facility at Northern Colorado (n=167 calving).

	Animal Observation				Environmental observation				
Animal Behavior	Prim.	Dyst.	Twin.	Calf Gender	Calving Patio	Drop Time	High Temp.	Low Temp.	Heat Index
Nursing DC	0.52	0.67	0.78	0.2	0.16	0.13	0.64	0.3	0.68
Avoidance DC	0.25	0.85	0.53	0.7	0.17	0.87	0.07*	0.03**	0.55
Aggressive DC	0.02**	0.59	0.74	0.43	0.37	0.06*	0.21	0.14	0.53
AggressiveD	0.06*	0.32	0.53	0.31	0.0004***	0.32	0.55	0.06*	0.59
SubmissiveD	0.06*	N/A	N/A	0.23	0.49	0.16	0.33	0.15	0.54
Aggressive Dcow	0.05**	0.17	0.38	0.62	0.0002***	0.47	0.88	0.09*	0.55
AggressiveD sep	0.65	0.76	0.85	0.26	0.67	0.34	0.57	0.65	0.57
Licking CD	0.51	0.17	0.39	0.04**	0.36	0.001***	0.39	0.88	0.16
Licking CCow	<0.0001***	0.15	0.34	0.27	0.01**	0.33	0.77	0.72	0.88
SurrogateCow/Calv.	0.69	0.61	0.47	0.13	0.04**	0.66	0.14	0.1	0.89
SurrogateCow/after	0.8	0.19	0.21	0.65	0.47	0.28	0.96	0.46	0.13
Following DC	0.75	0.08*	0.11	0.59	0.26	0.59	0.4	0.41	0.69
Looking DC	0.81	0.01**	0.4	0.81	0.48	0.83	0.87	0.6	0.77
Sucking CD beh	0.003***	0.06*	0.22	0.21	0.021*	0.02**	0.69	0.25	0.7
StandupC	0.12	0.003***	0.04**	0.59	0.05**	0.008***	0.89	0.15	0.8
Looking CD	0.49	0.39	0.29	0.18	<0.0001***	0.02**	0.16	0.11	0.09*

[1]D refers to the Dam, C to the calf (neonate), and Cow to another cow in the herd (no the cow). The Upper case for the animal also indicates the direction; DC is Dam to Calf, CD is Calf to Dam, DCow is Dam to another cow, and Ccow is Calf to another Cow. Asterisks indicate levels of significance: *P ≤ 0.10; **P ≤ 0.05; ***P ≤ 0.01.

Table 3.7. Estimated differences of animal and environmental observations Least Squares Means Adjustment for Multiple Comparisons: Tukey-Kramer, compared to Dam and Calf behaviors right after calving and up to separation, accounting for DC time together (Mean= 40.87min, SD=31.17min), in a maternity facility at Northern Colorado (n=167 calving).

Variable	Dam behavior (D)[1]			Calf behavior (C)[1]			
Animal Parameter	Licking DC (30ss)	Licking DC (2min)	Licking DC (5min)	Licking CD	Licking CCow	Sucking CD (beh)	StandupC
Multiparous	1,196	1,812	2,272	2,230	12,315	9,463	1,912
Primiparous	881	1,770	3,923	2,849	1,904	147	1,387
P-value	0.09*	0.86	0.002***	0.63	0.31	0.24	0.12
Eutocia	1,164	1,803	2,470	2,368	7,357	6,260	1,789
Dystocia	819	-	1,167	-	-	-	-
P-value	0.01**	<0.0001***	0.36	<0.0001***	0.16	0.08*	<0.0001***
No Twin	1,145	1,787	2,437	2,368	7,357	6,261	1,789
Twin	1,163	2,766	-	-	-	-	-
P-value	0.97	0.25	<0.0001***	<0.0001***	0.16	0.08*	<0.0001***
F Calf	1,125	1,652	2,246	1,946	1,446	1,099	1,642
M Calf	1,162	1,911	2,594	2,488	10,313	8,964	1,895
P-value	0.79	0.20	0.34	0.47	0.42	0.31	0.37
Environmental Parameter							
Calving Inside	1,160	1,852	2,456	2,410	1,712	2,980	1,906
Calving Patio	1,055	1,557	2,332	2,221	18,648	14,644	1,396
P-value	0.607	0.271	0.805	0.771	0.105	0.139	0.107
AM drop time	1,232	1,861	2,460	2,350	1,803	2,604	1,678
PM drop time	1,056	1,723	2,407	2,457	14,763	13,242	1,961
P-value	0.21	0.4	0.884	0.88	0.24	0.14	0.33
High Temp.							
>106F	1,120	1,748	2,385	2,113	2,051	2,980	2,063
97-106F	1,450	1,648	2,507	2,312	31,362	18,740	1,909
85-97F	979	1,931	2,531	2,323	1,594	2,595	1,651
P (hi-low)	0.2542	0.941	0.9755	0.986	0.099*	0.438	0.937
P (hi-med)	0.743	0.771	0.945	0.966	0.999	0.999	0.532
P (low-med)	0.02**	0.44	0.99	0.99	0.04**	0.21	0.78
Low Temp.							
High	1,185	1,586	2,475	1,909	4,534	3,824	1,592
53-57F	1,285	1,885	2,530	2,071	31,527	13,947	1,831
<53F	1,065	1,842	2,377	2,686	789	2,162	1,829
P (hi-low)	0.88	0.64	0.99	0.98	0.16	0.57	0.85
P (hi-med)	0.79	0.61	0.97	0.46	0.95	0.98	0.82

P (low-med)	0.38	0.98	0.93	0.67	0.03**	0.3	1
Heat Index							
hig-low2	1,080	1,736	2,298	2,175	2,544	2,693	1,590
hig-med2	1,324	1,637	2,124	2,328	24,645	21,303	2,036
low-med2	1,095	1,948	2,718	2,507	1,496	2,860	1,797
P (hi-low)	0.42	0.93	0.93	0.99	0.21	0.13	0.46
P (hi-med)	0.99	0.63	0.56	0.81	0.99	0.99	0.79
P (low-med)	0.39	0.43	0.39	0.99	0.14	0.10	0.77

[1] D refers to the Dam, C to the calf (neonate), and Cow to another cow in the herd (no the cow). The Upper case for the animal also indicates the direction; DC is Dam to Calf, CD is Calf to Dam, DCow is Dam to another cow, and Ccow is Calf to another Cow.

[2] Estimated difference of value1 vs. value2 (in seconds).

[3] The values no reported was due to missing values analyzed, behaviors no reported for specific parameter. Asterisks indicate levels of significance: *$P \leq 0.10$; **$P \leq 0.05$; ***$P \leq 0.01$.

Table 3.8 Estimated coefficients and odd ratios from a cumulative logistic multinomial regression for the association between animal behaviors with animal-level and environmental variables right after calving, accounting for time together, in a maternity facility at Northern Colorado (n=167 calving).

Animal behavior[2]	OR[1]	*P*-value	95% CI
Aggressive DC			
Multiparous vs. Primiparous	0.08	0.05*	(0.007, 1.033)
Aggressive Dcow			
Multiparous vs. Primiparous	0.34	0.08*	(0.1, 1.13)
Calving alone (0) vs. 1	3.39	0.09*	(0.8, 13.9)
Calving patio (0) vs. 1	0.17	0.002***	(0.05, 0.5)
AggressiveD			
Multiparous vs. Primiparous	0.47	0.23	(0.1,1.6)
Calving patio (0) vs. 1	0.17	0.004***	(0.05,0.5)
Avoidance DC			
Tlow high vs. med	4.02	0.14	(1.005,16.1)
Tlow low vs. med	<0.001		(<0.001,>999.99)
Calving patio (0) vs. 1	0.19	0.04**	(0.04,0.9)
Following DC			
Dystocia 0 vs. 1	6.68	0.08*	(0.7,58.3)
Licking Ccow			
Multiparous vs. Primiparous	0.11	0.0003***	(0.03, 0.3)
Calving patio (0) vs. 1	0.3	0.05**	(0.09,0.9)
Licking CD			
PM vs AM	5.1	0.01**	(1.4, 18.9)
Looking CD			
PM vs AM	1.99	0.16	(0.7, 5.2)
Calving patio (0) vs. 1	0.16	0.0003***	(0.06, 0.4)
Looking DC			
Dystocia 0 vs. 1	3.92	0.03**	(1.1,13.1)
Standup C			
PM vs AM	1.77	0.14	(0.8,3.8)
Standup Intent			
PM vs AM	1.72	0.17	(0.7, 3.7)
Multiparous vs. Primiparous	0.4	0.07*	(0.1, 1.9)
Sucking CD Beh			
Multiparous vs. Primiparous	0.17	0.002***	(0.05,0.5)
Calving patio (0) vs. 1	0.35	0.06*	(0.1,1.06)
Sucking CD Beh			
PM vs AM	3.48	0.28	(0.3, 33.2)
Calving patio (0) vs. 1	0.08	0.008***	(0.01,0.5)
Surrogate Cow at calving			
Calving patio (0) vs. 1	2.53	0.05*	(0.9, 6.5)
PM vs AM	1.06	0.86	(0.5, 2.05)

[1] Odd ratio (OR) coefficient.

[2]All behaviors were tested accounting for the time together between the dam and the calf. Asterisks indicate levels of significance: $*P \leq 0.10$; $**P \leq 0.05$; $***P \leq 0.01$.

Table 3.9. Chi-square test of association between the Dam (D) and the Calf (Calf) behavior after calving up to separation, compared to health performance of the dam and the calf up to 14 days after birth, in a maternity facility at Northern Colorado (n=167 calving).

Behavior	Health Dam	Left Dam	Health Calf	Left Calf	Left Dam
LickingCD	0.04**	0.49	-	0.48	0.35
NursingDC	0.95	0.57	-	0.82	0.82
AvoidanceDC	0.33	0.04**	-	0.61	0.10
Aggressive DC	-	0.23	-	0.78	0.78
Aggressive Dcow	0.84	0.14	0.04**	0.35	0.48
LickingCCow	0.90	0.39	0.5	0.45	0.44
Surrogateat calving	0.37	0.38	-	0.03**	0.24
Surrofate after	0.54	0.25	-	0.15	0.15
SubmissiveD	0.2005	0.27	-	0.49	-
AggressiveD	0.79	0.86	0.04**	0.62	0.37
FollowingDC	0.73	0.93	0.25	0.86	0.23
LookingDC	0.15	0.75	0.25	0.49	0.49
LookingCD	0.85	0.06*	0.5	0.57	0.57
AggressiveD Sep	0.17	0.14	-	0.87	0.87
Sucking CD beh	0.81	0.95	-	0.32	0.32
Standup Intent	0.67	0.64	0.5	0.57	0.63

D refers to the Dam, C to the calf (neonate), and Cow to another cow in the herd (no the cow). The Upper case for the animal also indicates the direction; DC is Dam to Calf, CD is Calf to Dam, DCow is Dam to another cow, and Ccow is Calf to another Cow.
Asterisks indicate levels of significance: *$P \leq 0.10$; **$P \leq 0.05$; ***$P \leq 0.01$.

Table 3.10. Estimated differences of ADG compared to the presence of dam and calf behaviors right after calving and up to separation in a maternity facility located in Northern Colorado (n=167 calvings).

Behavior	Estimated Calf Average Daily Gain (ADG)		
	No behavior	Yes behavior	*P*-value
Licking CD	1.55	-	<0.0001***
Nursing DC	1.55	-	<0.0001***
Avoidance DC	1.56	1.14	0.14
Aggressive DC	1.56	1.1	0.24
Aggressive Dcow	1.49	2.12	0.0009***
Licking CCow	1.51	2.03	0.02**
Surrogate at calving	1.64	1.46	0.12
Surrofate after	1.52	1.61	0.48
Submissive D	1.43	2.03	0.11
Aggressive D	1.50	1.79	0.18
Following DC	1.57	1.52	0.65
Looking DC	1.56	1.54	0.86
Looking CD	1.53	1.65	0.50
AggressiveD Sep	1.55	1.33	0.58
Sucking CD beh	1.52	1.86	0.08*
Standup Intent	1.47	1.78	0.01**

D refers to the Dam, C to the calf (neonate), and Cow to another cow in the herd (no the cow). The Upper case for the animal also indicates the direction; DC is Dam to Calf, CD is Calf to Dam, DCow is Dam to another cow, and Ccow is Calf to another Cow.
Asterisks indicate levels of significance: $*P \leq 0.10$; $**P \leq 0.05$; $***P \leq 0.01$.

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