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# Associations Between Activity Patterns During the Dry Period and Calving Events in Dairy Cattle

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## ABSTRACT

The objective of this study was to assess the associations of dry period management practices and activity patterns (i.e., lying time, number of lying bouts, and lying bout duration) during 14 days prior to calving. Heifers and cows from four dairy farms (700-2,800 milking cows) located in Pennsylvania were enrolled in this trial. Based on on-farm records, cows that were between 20 and 30 days from expected calving date were fitted with a HOBO® accelerometer on the rear right leg. Only animals that had complete activity data for 14 days before the actual calving date were included in the study (heifers, n=66; cows, n=70). A 20-question multiple-choice survey was developed to collect farm management practices information (e.g., feed push-up frequency, bedding material used). The data were analyzed using the MIXED procedure of SAS. Heifers and cows that were housed in pens with sand or straw as bedding materials spent more time lying (sand=815.7±12.01 min/d; straw=845.61±21.68 min/d; sawdust/recycled manure=650.30±17.06 min/d), and had more lying bouts (sand=11.18±0.25 bouts/d; straw=12.69±0.51 bouts/d; sawdust/recycled manure=9.45±0.37 bouts/d) and of shorter duration (sand=75.02 min/d, 95% CI:56.79-99.13; straw=66.21 min/d, 95% CI:56.98-76.93, sawdust/recycled manure=98.31 min/d, 95% CI:67.92-142.30) compared to cows that were housed in pens with either sawdust or recycled manure as bedding materials. Furthermore, heifers and cows that were fed two times a day spent nearly 3 hours less lying down (two times feeding= 650.36±22.05 min/d; one time feeding=823.77±13.57 min/d) and tended to have longer lying bouts (two times feeding= 98.33 min/d, 95% CI:65.61-147.37; one time feeding=72.23 min/d, 95% CI:58.30-89.47) compared to cows that were fed one time a day. The results from this study suggest that farm practices during the dry period may affect cow behavior, which can have significant effects on cow health and welfare.

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# Chapter 1
# Literature Review

## Cow Behavior Patterns

Cow behavior has been used as a parameter to assess cow comfort and animal welfare in dairy farms for the last several years. Cows must have an appropriate daily time budget in order to be able to perform natural behaviors such as lying down and ruminating, which are important for them in order to properly perform and avoid becoming sick with infectious or metabolic diseases such as lameness and ruminal acidosis. As industry benchmarks, it has been established that dairy cows housed in freestall barns should spend 11.9 h lying down, 4.3 h feeding, 2.5 h standing in the alley/drinking, 2.7 h milking and 2.7 h standing in the stall (Gomez and Cook, 2010). However, it has been reported that specific events such as disease events can alter cow behavior. For instance, Barragan et al. (2018) found that primiparous cows with clinical metritis spent more time lying down compared to primiparous cows without clinical metritis. Similarly, Menichetti et al. (2020) reported that cows that had a stillborn calf had reduced lying time 7 days prior to calving compared to cows that had a calf born alive. Monitoring cow activity patterns during the dry period may have the potential to predict important undesirable calving events, such as dystocia, allowing farmers to adjust farm management practices accordingly during calving to dimmish negative effects of these events.

## Normal Behavior During the Dry Period

Before assessing factors that affect cow behavior it is important to first determine the normal behavior of a cow during the dry period. The dry period of a cow is traditionally between six and eight weeks before calving. This is a period that the cow is not being milked. During this time, dairy cows must manage the exponential growth of the fetus, overcome the event of calving, and adapt to the increased physiological, metabolic, and nutritional demands imposed by the start of lactation (Grummer, 1995; Drackley, 1999; Roche et al., 2013). An important component of cow comfort and welfare is lying time (Munksgaard and Simonsen, 1996). In housed systems, lying behavior has been recognized as an early indicator of health problems (Weary et al., 2009). Understanding the effects of cow physiology, and management factors, on lying behavior and activity will improve our understanding of factors to take into consideration when using animal behavior as an indicator of health or welfare and help producers optimize the treatment of cows (Bewley et al., 2010).

## Physiologic Factors That Affect Cow Behavior

For a dairy cow, one of the most significant physiological changes that occurs during their life is the transition from a nonlactating to a lactating state (Grummer, 1995). As stated above lying time and frequency are important components of animal welfare and health. In a study done by Hendriks S. et al. (year), lying times were about 3 hours less before calving and about 1.5 hours less post calving (Hendrinks, 2019). Restlessness and discomfort around calving are likely to be responsible for the changes in behavior (i.e., repeatedly lying down and standing up and pacing; Huzzey et al., 2005; Borchers et al., 2017). Included in calving events is the increase of milk production, as stated in Norring et al. (2012), which leads to discomfort due to increased intramammary pressure, possibly contributing to a reduction in lying time (Norring et al., 2012). However, management practices such as confined housing have created higher energy requirements, increasing time spent eating, and have attributed to less time lying (Lovendahl and Munksgaard, 2016; Stone et al., 2017).

## Parity

Parity defines the different number of times a female has had an offspring. As parity of a cow increase, the milk yield of that cow increases. With increased parity, the cow will become more exposed to farm practices and become more comfortable with farm management; which in turn, will create less stress to the animal when handled. Stress of the animal can be shown in a multitude of ways, observing the cow's lying behavior is one of the most used methods of observing cow comfort. In a study done by Neave et al., (2017), a small significant parity difference in lying time was noticed with primiparous cows having slightly shorter times than multiparous cows in the week after calving (Neave et al., 2017). Primiparous cows also showed more transitions between standing and lying, as well as a shorter lying bout duration compared to multiparous cows (Neave et al., 2017). The decrease lying time observed in the primiparous cows indicates they are less comfortable and more stressed due to them being inexperienced with the farm management practices.

## Management

Management during the dry cow period can ultimately determine the health of a dairy cow, they require a clean dry environment that is free of stress. During the dry period, dairy cows are exposed to a multitude of management-related changes (Sepulveda-Varas et al., 2014). These management-related changes may cause stress to the animal in not allowing them to express normal dry cow behavior such as overstocking, frequent movement of the cows, comingling of parity and poor feed, bedding, and vaccination management. Physiological and management factors can constrain the time budgets of cows and drive differences in time required lying, feeding, ruminating, and in lactating cows being milked (Jensen et al., 2005; Norring et al., 2012). It has been observed that longer lying times have been observed in free stalls that are wider and more appropriately sized to the size of the cow using them (Tucker et al., 2004; Solano et al., 2016; Morabito et al., 2017).

## Cow Movement Frequency

Cow movement frequency refers to the number of times the cow is moved to different pens throughout the farm during their dry period. It is important to track these movements due to the possibility of antagonistic relationships and formations of social hierarchy. As stated by Cook and Nordlund (2004), moving cattle between groups causes increased social interactions, such as antagonistic behaviors, before stabilization and development of a social hierarchy. However, development of a social hierarchy could mean younger cows not obtaining the nutrients they need and older cows obtaining too much of the nutrients. Cook and Nordlund (2004) found that, although the effect of pen moves on the average cow appears to be modest, the effect appears to be more significant on low-rank cows. In a study done by Phillips and Rind (2002), they measured the differences in milk production between mixed and unmixed parity groups. In this study, authors found that cows assembled in unmixed groups produced 3% more milk in the first week than equivalent cows in the mixed groups (Phillips and Rind, 2002). Not only did this increase milk yield, but the results suggest it also increased total time lying down and ruminating in groups that were kept separated while in mixed groups had less time ruminating while lying down (Phillips and Rind, 2002). These findings suggest that cow movement frequency may have an impact on not only milk production, but increased stress incidence in the cow that can be observed by their lying time and rumination

## Dry Cow Management Practices

A dry cow is defined as a dairy cow that is in a stage in her lactation cycle where she is forced to stop producing milk, prior to calving. Generally, this stage of her lactation cycle last 40 to 65 days and it is referred to as the cow's dry period. Much research has shown that management practices during this time are critical to the overall milk production of the cow during their next lactation. Niemi et. al. (2022) preformed a study on dry cow therapy effects on milk yield and somatic cell count. The result proved that a missed antibiotic dry cow therapy for a high somatic cell count cow has a negative effect on subsequent lactation milk yield (Niemi et. al. (2022). Management practices are also critical in the overall health of the cow, if not dried off correctly this could introduce environmental pathogens that can cause mastitis. As stated by Dingwell et al. (2004), the probability of an intramammary infection during the dry period is influenced by the rate of exposure to potential pathogens (e.g., from the environment), factors that affect an individual cow's susceptibility to infection; and the effectiveness of protection from medical interventions such as antibiotic dry-cow therapy or teat sealants (Bradley and Green, 2001; Berry and Hillerton, 2002; Huxley et al., 2002; Robert et al., 2006). If the cow teat is not sealed correctly and develops an infection this may alters the cow behavior by causing them to reduce their feed intake and become restless from pain of the infection. The cow would have more lying bouts or less duration due to the constant getting up and down to reduce pain in the teat, and create a dull, lethargic cow from the reduced feed intake.

## Stocking Density

Stocking density in a confined system is defined as one cow per stall in a free stall barn (Cook and Nordlund, 2004). The barn becomes overstocked whenever the number of cows in the pen exceeds the number of free stalls, this caused an increase in social tension (Cook and Nordlund, 2004). Dairy producers using free-stall barns may overcrowd their lactating cows to improve financial returns on finicality investments (Bewley et al., 2001). However, this may interfere with the cow's ability to express natural feeding and resting behavior causing stress in the dairy cattle. In a study done by Wagner-Strorch et al. (2003), it was observed an average stall occupancy of only 74% at a stall stocking density of 100%. Spinka (2006) preformed a study to determine how important natural behavior is in animal farming systems. Spinka (2006) results suggest that stocking densities could be increased above 100% without necessarily interfering with the cow's ability to express natural resting behavior. However, in a study done by Fregonesi et al. (2007), when stocking density was increased from 100% to 150%, lying time was reduced linearly. Friend et al. (1977) found, there was no reduction in lying time until stocking density was increased to two cows per stall.

## Bedding Management

Bedding management refers to the main farm practices related to maintain an optimal lying surface for cows to properly rest such as bedding material type and stall cleaning frequency, among others. The importance of this in dairy barns is to increase lying time, and milk production of the dairy cows and most importantly decrease their risk of developing diseases such as mastitis. As proven in a study by Manninen et al. (2002), cows prefer bedding that is softer materials and improves surface traction in the stall making it easier for them to rise and lie down (Manninen et al., 2002). If the cow is more comfortable in the bedding, they are more likely to have more lying bouts of a longer duration. However, Cows spend 12 to 14 h/d lying down (Krawczel and Grant, 2009), so bedding management is an important factor affecting teat end exposure to the environment mastitis pathogens (Patel et al., 2019). It has also been reported that bedding bacterial counts are associated with bacterial load on the teat end (Bramley et al, 1975; Paduch et al., 2013; Rowbotham et al., 2016a). In a study done by Rowbotham et al. (2015) they determined what types of bedding increase milk production and found that farms on which manure product bedding was used contained more lactating cows than farms using inorganic bedding and had a greater proportion of milk not sold than farms using inorganic bedding. This indicates that the milk from farms using inorganic bedding is contaminated, thus, the teats of the cow more often have high bacterial loads with a greater risk of developing disease. If the cows were to develop disease, they would have less lying bout duration due to infection such as mastitis.

## Feeding Management

Feeding management entails managing the quantity of available nutrients fed to the cow in their feed. It has been proved that improved feed management during the transition period of dairy cows has shown improved performance of dairy cows in terms of production (Singh et al, 2020a), reproduction (Drackley et al, 2005), health and reduced energy balance (Overton and Waldron, 2004). Reduction of dry matter intake (DMI) during the pre-partum period leads to increased depletion of body reserves and hence leads to negative energy balance (nEB) (Roche et al., 2013; Drackley and Cardoso, 2014; Singh et al, 2020a). With a decrease in DMI, there will be an increase of nEB in dairy cows which has shown to have a sharp decline in body condition of dairy cows, poor milk performance and udder health status (Berry et al., 2007; Bhakat et al., 2017; Alhussien and Dang, 2018; Singh et al., 2020d; Singh et al., 2020g). High nEB leads to immunosuppression during transition period which may lead to a potential risk for impairment of mammary function of dairy cows thereby reduced udder health status may take place which ultimately causes poor quality milk in dairy cows (Berry et al., 2007). This ultimately increases the cows risk of developing diseases such as mastitis which will ultimately lead to the cow being uncomfortable which will cause less lying bout duration and frequent rising and lying down. However, some studies have found that despite increased feeding time, and fresh feed delivery, the cows lying patterns had not changed, which would be due to lying being the greatest priority for dairy cows (DeVries and von Keyserlingk, 2005, Hart et. al., 2014).

## Vaccination Practices

Vaccination practices are often used in dairy herds to immunize cows to common pathogenic agents. Common agents immunized against are Parainfluenza-3 (PI3) virus, Bovine Respiratory Syncytial Virus (BRSV), Infectious Bovine Rhinotracheitis (IBR) virus, Bovine Viral Diarrhea (BVD) virus, leptospirosis, and clostridial infections. In a study done by Courcoul et al., it was found that a phase I vaccination, vaccination of the whole herd for 10 years was the most effective control strategy. However, the study has also shown that all three vaccination strategies, vaccination of the whole herd for 10 years, vaccination of the whole heard for 3 years and vaccination of the heifers for only 10 years, were effective in reducing the prevalence of shedders, the environmental bacterial load, and the number of abortions; although all three scenarios were not as equivalent in their effectiveness (Courcoul et al., 2011). Although not all vaccination methods were as effective as the next, this study shows that any of these vaccination processes were effective in decreasing the spread of the disease, which is crucial in dairy herd for the productivity of the herd and economically for the farmer. Vaccination of the cows will lower their risks of developing diseases such as mastitis and metritis. These diseases will alter the cow's behavior by reducing feed intake, decreasing lying bout duration and increasing frequency of rising and lying down. However, Hilton et al. (2021), preformed a study to determine the effects of vaccinations against brucellosis and clostridia on the intake, performance, feeding behavior, blood parameters, and immune response of dairy heifers' calves. The results of this study indicated that the concomitant vaccination against brucellosis and Clostridia has no relevant impact on the intake, performance, and feeding behavior of dairy calves (Hilton et al., 2021).

## Commingling by Parity

Commingling by parity entails combining cow of different parity together in groups. Social status affects several behaviors, such as feed and water intake, in groups and individually (Andersson and Lindgren, 1987; Ingrand, 2000; Phillips and Rind, 2002). This may happen in cow groups of commingling parity due to heifer, being much smaller than cows (cows that had at least one calf). In a study done by Andersson et al. (1984), it was found that dominant cows drink more water and produce more milk than subordinate cows in the same group. One study reported that first- lactation cows housed separately from multiparous cows had longer feeding times, increased feeding frequency, greater feed intake, and higher milk yield compared with first-lactation cows mixed with older cows (Neave et. al., 2017). These support the results shown by Lindberg (2001), that reported that dominance rank in groups of animals may result in a few top-ranking individuals getting plenty and the rest little resources, such as water and feed, or the majority getting equal distribution and the lowest ranking animals getting very little.

# Chapter 2

## Statement of the Problem and Rationale

Management practices are well developed to adapt to the cows needs. However, when farm management practices are inappropriate for the cow they can challenge their physiology and welfare wich leads to increased risk of disease and poor performance. Known challenges of these inappropriate management practices causes welfare practices (e.g., stillbirth) and calving-related losses. However, if we were able to identify inappropriate management practices associated with stress and poor welfare that may lead to undesirable events such as dystocia, farmers and producers could adjust their management accordingly. This will ultimately reduce the stressors on the dairy herds, making animal more productive and allow farms to become more economically efficient. The objective of this study was to assess the associations of dry period management practices and activity patterns (i.e., lying time, number of lying bouts, and lying bout duration) during 14 days prior to calving. The hypothesis was different management practices would have different effects on cow behavior and inflammatory status during the dry period.

# Chapter 3

## Introduction

The dry period is one of the most significant physiological changing periods for a dairy cow. The dry period is the period six to eight weeks before calving where the dairy cow is not milked. During this time, dairy cows must manage the exponential growth of the fetus, overcome the event of calving, and adapt to the increased physiological, metabolic, and nutritional demands imposed by the start of lactation (Grummer, 1995; Drackley, 1999; Roche et al., 2013). During the dry period, management practices ultimately can determine the health of a dairy cow. Much research done by Niemi et al. (2022), Dingwell et al. (2004), Wagner-Strorch et al. (2003), Spinka (2006), Fregonesi et al. (2007), and Friend et al. (1977) have shown that management practices and providing a clean dry environment that is stress free during this time are critical to the overall milk production of the cow during their next lactation. If it is determined what management practices cause stress during the dry cow period, management could ultimately be modified to increase the welfare and performance of dairy cows. To assess the cow's comfort and animal welfare during this period, dairy farms, for the last several years, have focused on the cow's behavior patterns, such as lying time and frequency. Cows need an appropriate time budget to perform these natural behavior patterns such as lying down and ruminating to properly preform and avoid becoming sick with infectious or metabolic diseases such as lameness and ruminal acidosis.

Management practices that may alter the behavior patterns are the stocking density, bedding management, feeding management, vaccination practices and commingling of parity. Overcrowding may interfere with the cow's ability to express natural feeding and resting behavior causing stress in dairy cattle. In a study done by Fregonesi et al. (2007), when stocking density was increased from 100% to 150%, lying time was reduced linearly. Cows generally spend 12 to 14 h/d lying down (Krawczel and Grant, 2009), so bedding management plays an important role in dairy barns by increasing lying time and milk production of the dairy cows and most importantly decreases their risk of developing diseases such as mastitis. It has been proven that improved feed management during the transition period of dairy cows has shown improved performance of dairy cows in terms of production (Singh et al, 2020a), reproduction (Drackley et al, 2005), health and reduced energy balance (Overton and Waldron, 2004). A reduction in a dairy cow's dry matter intake (DMI) can lead to negative energy balance (nEB). Which can lead to immunosuppression that may cause impairment of mammary function and reduced udder health that will ultimately cause poor quality of milk (Berry et al., 2007). Ultimately, the nEB and the development of immunosuppression will make the cow at higher risk of developing disease and will create a behavioral change in the cow. Similarly, vaccinations practices can affect cow behavior during the dry period by protecting them from developing disease. Commingling cows by parity may require moving cows which creates a social turmoil, where social hierarchy must be re-stablish. On top of this stressor, high parity animals outcompeted younger smaller animals, getting plenty of resources while the lowest ranking individuals, low parity, have limited.

Improper management can lead to stress which may lead to a multitude of complications during the dry period such as dystocia and stillborn calves. If producers are able to determine what management practices cause stress that leads to these undesirable events, they can adjust their management practices accordingly, which will ultimately allow the producers to have a better animal welfare in their herds and become more economically efficient.

Therefore, the objective of this experiment was to assess the effects of management practices during the dry cow period on (1) the behavior of the cow, (2) BCS and systemic inflammation (haptoglobin) and (3) incidence of calving events (e.g., dystocia, stillborn calves. We hypothesis that different management practices would have different effects on cow behavior and inflammatory status of cows during the dry period.

# Chapter 4

## Materials and Methods

The procedures of animal use were reviewed and approved by the Pennsylvania State University IACUC (Protocol: 202001505).

### Animal Facilities and Feeding

This experiment was performed on four commercial dairy farms (A, B, C, D) located in central Pennsylvania, between August 2020, and February 2021. Descriptive information of study farms is presented in Table 1. A 20-question multiple-choice survey was developed to collect farm management practices information (e.g., feed push-up frequency, bedding material used) from each farm.

**Table 1. Select questions and answers from dairy farms A, B, C, and D from the 20-question multiple-choice survey.**

| | Dairy Herds | | | |
|---|---|---|---|---|
| Items | A | B | C | D |
| Farm Size | >1000 | >1000 | >1000 | 500-1000 |
| Number of personnel per 100 cows | 14p | 28-40 employees | 53. 4 employees | 1.7 per 100cows |
| Milking frequency<br>Type of barn? | 3 times/d<br>Freestall | 3 times/d<br>Freestall | 3 times/d<br>Freestall-far off Bedded pack-Close up | 3 times/d<br>Freestall-far off Bedded pack-Close up |
| Number of dry cow groups? | Other- 4 | 2 | 3 | 2 |

| | | | | |
|---|---|---|---|---|
| Type of flooring? | Grooved cement | Grooved cement-24y, Slats | Grooved cement, Rubber | Grooved cement-6y |
| Type of bedding | Sand | Solid/recycled manure, Sawdust | Sand | Sand-freestall Straw-maternity |
| Alley scraping method | Other- No Flush | Automatic scrappers, Skid-steer loader | Skid-steer loader | Automatic scrapers |
| How often stalls/ beds are raked? | Once a week | 3 times, mattresses cleaned every milking | 1 time a day | Once a month |
| How often is bedding replaced? | Other- never replaced, just add new bedding | Other- mattresses | other- never | other- every 3months-packpen/never-freestalls |
| How often are dry cows moved? | Weekly | Weekly | Weekly | Weekly-sometimes biweekly |
| Frequency of fresh feed delivery? | Once a day | Two times a day | Once a day | Once a day-dry cows |
| Are dry cows vaccinated/ how many days before expected calvings? | Yes- 250-256 Dcc is last vaccine | Yes- 21 days | Yes- 20-30 days | Yes- 21-28 days |
| How many hours are the lights on? | Most of night | 24h | Just to move calving’s | 4-6h |
| What cooling system do you use? | Fans and sprinklers/ ceiling vents | Fans, Sprinklers, Fans and sprinklers | Fans and sprinklers | Fans and sprinklers |

## Animal Enrollment and Assessment of Lying Time

The study was conducted on heifers and cows from four Holstein dairy farms (700-2,800 milking cows) located in Pennsylvania. Based on on-farm records, cows that were between 20 and 30 days from expected calving date were enrolled in this trial, blood from each cow or heifer was taken and they were fitted with a HOBO® accelerometer on the rear right leg (Figure 1). Only animals that had complete activity data for 14 days before the actual calving date were included in the study (heifers, n=66; cows, n=70). After calving the HOBO® accelerometer was collected along with blood samples of each cow.

**Figure 1. HOBO® pedometer device that was placed on the right hind legs of study animals to assess activity patterns.**

## Assessment of Haptoglobin and Body Condition Score

Blood samples were collected when the cow was fitted with the HOBO® accelerometer and within 7 days after calving. The samples were collected using 8.5-mL sterile serum tubes (Vacutainer; Becton, Dickinson and CO., Franklin Lakes, NJ), immediately after collection the tubes were stored on ice, and within 2 h of collection, the samples were centrifuged to (15 min at 1,400 x *g*, at room temperature [25°C]) to harvest the serum, which was then stored in the freezer at -20°C until further analysis. The concentrations of haptoglobin serum were determined with a commercially available bovine haptoglobin ELISA kit (Life Diagnostics, West Chester, PA), following the manufacturer's instructions. Duplicate wells were used to analyze all samples and calibrators. Each animal enrolled had a calculated

BCS score based on a 5-point scale at enrollment and after calving by the experiment crew. The BCS loss from calving to enrollment was calculated by subtracting BCS at enrollment from BCS at calving (Barragan et. al., 2020).

## Assessment of Calving Events

A calving record sheet was developed for farm personnel to collect specific calving related events: Calving difficulty (i.e., no assistance, mild assistance, severe assistance), Calf presentation (i.e., forward, backward, breech, large calf), Calf limb position (i.e., extended or deviated), and Other calving events (twin births, stillbirth, and calf sex).

## Statistical Analysis

The data were analyzed using the MIXED and GLIMMIX procedure of SAS. The UNIVARIATE procedure of SAS was used to assess the homogeneity and normality of variances (graphical method, such as histogram and Q-Q plot, and Barlett's tests; Shapiro-Wilk statistic) for the quantitative variables. The LSM and SEM of the statistical model are presented. The main variables of interest and their interactions were considered statistically significant if $P < 0.05$, and $0.05 < P < 0.10$ was considered a tendency.

# Chapter 5
# Results

## Assessment of Haptoglobin and Body Condition Score

Regardless of calving related events, cows and heifers from different farms had different HP concentration (Farm A = 40.01±8.85 µg/mL; Farm B = 0±8.5045 µg/mL; Farm C = 15.18±9.10 µg/mL; Farm D = 6.72±10.62 µg/mL; Farm E = 20.39±8.09 µg/mL; Farm F = 42.30±8.73 µg/mL; Farm G= 5.72±8.01 µg/mL). Cows had higher concentrations of HP compared to heifers (Cow = 27.01±4.40 µg/mL; Heifer = 6.97±5.38 µg/mL). With regard to calving related events, cows and heifers that had a female calf tended to have higher HP concentration compared to cows and heifers that had a male calf (Female calf cow/heifer = 30.46±6.84 µg/mL; Male calf cow/heifer = 15.39±6.17 µg/mL). Furthermore, cows and heifers that had a stillborn calf tended to have higher concentration of HP compared to cows and heifers that had an alive calf (stillborn calf cow/heifer =47.07±19.41 µg/mL; alive calf cow/heifer = 15.11±4.03 µg/mL). There was no difference on BCS between study farms.

## Assessment of Lying Time

On average, heifers spent less time lying down compared to cows during the 14 days prior to calving (Heifer=766.01±46.25 min/d; Cow=789.36±46.72 min/d; Figure 2). Heifers and cows that were housed in pens with sand or straw as bedding materials spent more time lying time (sand=815.7±12.01 min/d; straw=845.61±21.68 min/d; sawdust/recycled manure=650.30±17.06 min/d), and had more lying bouts (sand=11.18±0.25 bouts/d; straw=12.69±0.51 bouts/d; sawdust/recycled manure=9.45±0.37 bouts/d) and of shorter duration (sand=75.02 min/d, 95% CI:56.79-99.13; straw=66.21 min/d, 95% CI:56.98-76.93, sawdust/recycled manure=98.31 min/d, 95% CI:67.92-142.30) compared to cows that were housed in pens with either sawdust or recycled manure as bedding materials. Furthermore, heifers and cows that were fed two times a day spent nearly 3 hours less lying down (two times feeding= 650.36±22.05 min/d; one time feeding=823.77±13.57 min/d) and tended to have longer lying bouts (two times feeding= 98.33 min/d, 95% CI:65.61-147.37; one time feeding=72.23 min/d, 95% CI:58.30-89.47) compared to cows that were fed one time a day.

Heifers and cows that had a female calf spent more time lying down (female calf heifer/cow=793.66±46.78 min/d; male calf heifer/cow=761.71±46.21 min/d), had more lying bouts (female calf heifer/cow=11.81±0.72 bouts/d; male calf heifer/cow=10.44±0.71 bouts/d), and had shorter lying bouts (female calf heifer/cow=74.15 min, 95% CI:57.90- 94.93; male calf heifer/cow=82.49 min, 95% CI:64.25-105 88) compared to heifers and cows that had a male calf (Figure 2). Heifers and cows that experienced a severe assisted calving spent more time lying down during the 14 days prior to calving compared to cows that experience either normal or mild assisted calving (no assistance calving cows= 786.68±44.84 min/d; mild assistance calving cows=722.75±48.85 min/d; severe assistance calving cows=823.63±53.32 min/d; Figure 3).

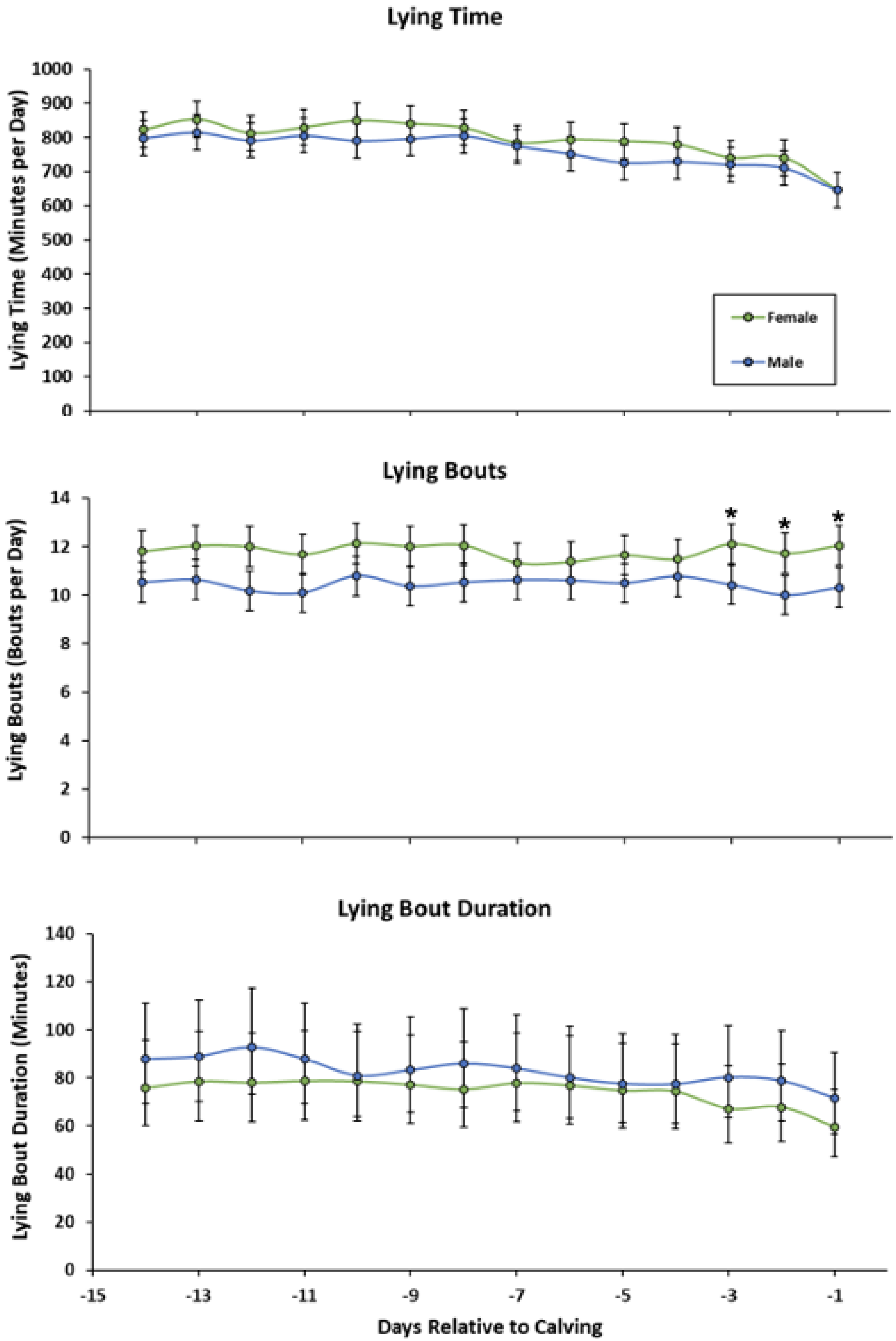


**Figure 2. Daily lying time (LSM±SEM; min/d), lying bouts (LSM±SEM; bouts/d), and lying bout duration (geometric means±95% CI; min) for 14 days before calving of heifers and cows that had a female (heifers n=32; cows n=30) or a male (heifers n=34; cows n=40) calf. * *P*-value <0.05.**

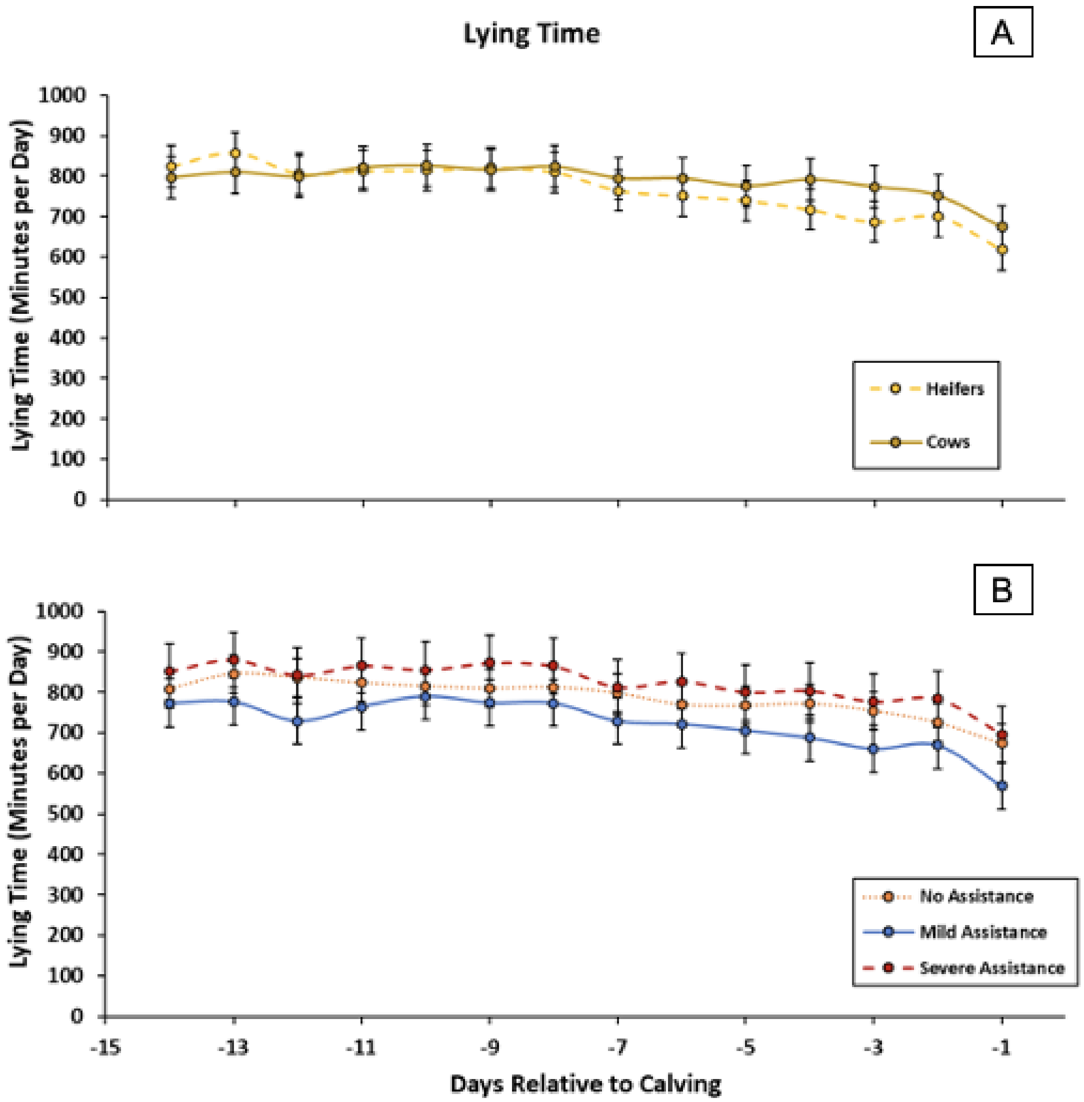


**Figure 3.** **Daily lying time (LSM±SEM; min/d) for 14 days before calving of (A) heifers and cows (heifer=66; cows=70), and (B) cows and heifers that experienced no assistance (heifers n=50; cows n=61), mild assistance (heifers n=10; cows n=7) or sever assistance (heifers n=6; cows n=2), at calving.**

# Chapter 6
# Discussion

The present study was designed to assess whether management practices affected the daily activity patterns (i.e., lying time, number of lying bouts, and lying bout duration) and calving events during the dry period in lactating dairy cattle.  The main results of this study showed: 1) farm and calving events, such as calf sex and stillbirth, affected HP concentrations, and 2) lying time in cows and heifers was affected by farm practices and calving events. Interestingly, HP concentration in both cows and heifers that had a female calf were significantly increased compared to cows and heifers that had a male calf.

Overall, regardless of calving related events, cows and heifers from different farms had different HP concentrations. This is to be expected, each farm has varying management practices during the dry cow period that will cause varying levels of inflammation on the cows depending on their sanitary practices. For example, farms that clean bedding and equipment more frequently will have a decreased risk of disease, thus a deceased inflammation frequency in their cows. Similar results have been found in a study done by Patel et al. (2019) stating that cows spend 12 to 14 h/d lying down (Krawczel and Grant, 2009); so bedding management is an important factor affecting teat end exposure to the environment mastitis pathogens (Patel et al., 2019). However, the results had indicated that cows tended to have a higher concentration of HP compared to heifers. This is due to as parity increases in a cow, they become more susceptible to infections, which will raise the cow's concentration of HP. This was demonstrated in a study by Ji-Yeon Lee (2006), as parity increases in a dairy cow so does the risk of retained placenta, metabolic disorder, and endometritis (Ji-Yeon Lee,2006). In addition, cows with parity of 4 or higher have more of a delayed recovery than those with party of 1, 2, and 3 until 3 months after lactation; and continuously delayed less than cows with parity of 1 until after 5 months of lactation (Ji-Yeon Lee, 2006).

Interestingly, both cows and heifers that had a female calf tended to have higher concentration of HP, spent more time lying down, had more lying bouts, and had shorter lying bouts, compared to cows and heifers that had a male calf. To our knowledge, this is the first published evidence that cows and heifers that have female calfs tend to have higher HP concentrations, spent more time lying down, had more lying bouts, and had shorter lying bouts. A hypothesis to why the HP concentrations are higher in dams with female calfs may be related to the gestation length and size of the calf as well as possible hormones released by the calf. These hormones may be interfering with the dam causing the high HP concentration. The calf size is generally smaller and gestation length is generally shorter in female calfs, this could lead to higher HP concentrations and may also be the result of the more time lying down, more lying bouts, and shorter lying bouts. Having more lying time and lying bouts may increase the dam's risk of developing disease. The dam having spent more time lying down, more lying bouts, and shorter lying bouts, may be due to the size of the calf, being that female calfs are generally smaller, this may make it easier for the dam to get up and down resulting in more lying time and lying bouts.

The results have also indicated that cows and heifers that had a stillborn calf tended to have higher concentration of HP compared to cows and heifers that had an alive calf. There are numerous infectious and noninfectious causes of dairy cattle stillbirths that will increase stress on the cow either before or after parturition that will increase HP concentrations. A recent study found, the most common noninfectious cause of bovine stillbirths is moderate and severe calving assistance and even slight calving assistance are associated with increased risk of stillbirths (Paulina J., et. al., 2017). While infectious agents account for between 3 and 12% of stillbirths diagnosed internationally in necropsy studies (Paulina J., et. al., 2017). As discussed previously, cows that are exposed to contaminates and equipment more frequently during calving are more likely to develop diseases, thus higher HP concentration. In addition, the cause of still birth could also be linked to infectious agents in utero, which would cause higher HP concentrations in the cow.

Lying time is an important parameter used to assess cow comfort and welfare. As seen in the present study's results heifers spend less time lying down compared to cows during the 14 days prior to calving. This is due to the proven phenomenon that as parity increase the lying time of the cow increases.

Westin et al. (2016) found in their study, some of the variation in lying time between cows was related to parity and stage of lactation, with older cows and cows at a later stage of lactation lying down in longer bouts (Westin et. al., 2016). This is in agreement with previous research done by Vasseur et al. (2012), who also suggest that it may be easier for primiparous cows to get up and lie down during early lactation, which may be why we observe less time lying down and more lying bouts (Vasseur et al., 2012).

Comfort of the stalls and bedding material are factors that also play an important role in lying time and lying bouts of dairy cattle. The results show heifers and cows that were housed in pens with straw and sand as bedding materials spent more time lying, more lying bouts and of shorter duration compared to cows that were house in either sawdust or recycles manure as bedding materials. The increased lying time and lying bouts in the sand and straw would be due to the softness of the material. As proven in Manninen et al., cows have a preference for lying on softer materials (Manninen et al., 2002). Other research suggests that cows may prefer bedding, like sand, that helps them to rise and lie down by improving surface traction in stalls (Manninen et al., 2002).

# Chapter 7

## Conclusion and Future Work

The study results suggest that monitoring cow behavior before calving may have the potential to predict important calving events, ultimately helping farmers to plan farm management practices accordingly. The results also suggest that lying time in cows and heifers was affected by farm practices and lying time can be used to determine important caving events that can ultimately help farmers plan accordingly for such calving events. Furthermore, these results suggest that farm management during the dry period may affect cow inflammation, and that inflammation during the dry period may be associated to important calving events. Further research should be focused on developing preventive practices during the dry period to modulate cow inflammation and assess the applicability and accuracy of this practice in commercial farm settings. Further research should also be focused on determining what causes dams that have a female calf to have higher concentration of HP, spent more time lying down, more lying bouts, and had shorter lying bouts.

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## ACADEMIC VITA


# Mikel N. Shabloski

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### EDUCATION

**Bachelor of Veterinary Biomedical Sciences,** **May 2022**

The Pennsylvania State University, University Park, PA

- Pennsylvania State University Dean's list **2018- Present**
- Penn State Schreyer's Honors College **2020 - Present**

**Graduation of High school** **2018**

Wellsboro Area High School, Wellsboro, PA

### OTHER WORK EXPERIENCE

**Penn State Veterinary Extension Team at the Central Milk Testing Lab**

**June 2020 – Present**

- Working in the lab separating blood samples and maintaining a clean working environment.
- Taking blood samples and placing pedometers on cows in various farms around the State College area.

**Penn State Beef and Sheep Centre** **May 2021 – Aug. 2021**

- Care for the beef cattle and sheep at the Beef and Sheep Centre by feeding, watering, and giving shots to the animals.
- Care for the facility by sweeping, cleaning animal pens, cleaning animal water and feed facilities, and cleaning equipment.

**Happy Hound Campground Boarding, Spa and Kennel** **May 2020 – May 2021**

- Cared for the canines boarding in the facility, and the facility by cleaning pens, beds, water, and food bowls.

- Cared for the canines bred, housed, and sold in the kennel.
- Groomed and bathed canines brought to the spa.

**Remley Farms** **May 2020 - May 2021**

- Care for the pigs at Remley farms by feeding, watering, and giving shots to the pigs.

**Red Skillet** **July 2019 - Aug. 2019**

- Managing orders, cooking food and helping customers while maintaining a clean working environment.

**Johnny'z Hot Rod Café** **June 2017 - Aug. 2018**

- Managing orders, cooking food, and helping customers while maintaining a clean working environment.

## INTERNSHIPS

**Penn's Cave and Wildlife Park** **May. 2019 – July 2019**

- Gave boat tours through the cave to visitors of the park and kept the establishment clean and presentable.

## COLLEGIATE CLUBS

**Pre-Veterinary Club** **2020 – Present**

- General meetings are held with mandatory attendance by all members where all club business is discussed.

**Lion Ambassadors** **2020 – 2020**

- Tours are given to interested students and parents of the Penn State Altoona campus, General meetings and committee meetings are held with mandatory attendance by all members, all club business is discussed at these general meetings.

**Biology Club** **2019 – 2020**

- General meetings are held with mandatory attendance from all members where all club business is discussed.

**Agriculture Club** **2018 – 2020**

- General meetings are held with mandatory attendance by all members where all club business is discussed.
- As Secretary, I recorded all club minutes, attendance, old business and new business from each general and officer meeting.

**Reserve Officer Training Corps.** **2018 – 2019**

- Physical Training is held every weekday except Friday, with classes on Tuesday and Thursday and lab on Wednesday. The classes were used to learn about the ARMY, the labs are to put those skills learned in class to use in the field.

## COMMUNITY SERVICE

Centre Wildlife Care **2021**

Centre Wildlife Care **2020**

Penn State University Altoona Campus, Sweat for Vets **2018**

Penn State University Altoona Campus, Voluntoona **2018**

Goodies For Our Troops **2016 – 2017**

## AWARDS AND HONORS

FFA Keystone Degree **2018**

## GRANTS RECEIVED

CARES Act Grant **2019-2020**

Penn State Academic Grant **2019-2022**

| | |
|---|---|
| Pennsylvania State Grant Fall Full Time | **2018-2021** |
| Pennsylvania State Grant Spring Full Time | **2019-2022** |
| Federal Supplemental Education Opportunity Grant | **2018-2019** |

**SCHOLARSHIPS**

| | |
|---|---|
| T&S Spring Scholarship in Agriculture Sciences | **2021- 2022** |
| R&S Storch Trustee Scholarship | **2021 - 2022** |
| George H Deike Scholarship | **2021 - 2022** |
| College of Agriculture General Scholarship | **2021 - 2022** |
| Summer Success Scholarship | **2021** |
| Undergraduate Scholarship for Talented Student | **2020- 2022** |
| Lindquist Trustee Scholarship | **2020 - 2021** |
| Donaldson Trustee Scholarship | **2020 - 2021** |
| A. Hartman Trustee Scholarship Agriculture | **2019 - 2020** |
| William H and M. Jean Coleman E Scholarship | **2019 - 2020** |
| John Potter Scholarship Agriculture | **2019 - 2020** |
| Hugh Gerhard Scholarship Agriculture | **2019 - 2020** |
| Bowen Copp Four Year Scholarship | **2018 - 2022** |
| Campus Four Year Provost Award | **2018 - 2022** |
| Wellsboro Library Club Scholarship | **2018 - 2019** |
| Wellsboro Social Club Scholarship | **2018 - 2019** |