EFFECTS OF HOUSING BEEF COW-CALF PAIRS ON DRYLOT OR PASTURE ON COW PERFORMANCE AND REPRODUCTION AS WELL AS CALF PERFORMANCE AND BEHAVIOR THROUGH FEEDLOT RECEIVING

BY

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THESIS

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ABSTRACT

The objectives were to analyze the effects of housing cow-calf pairs in drylots (**DL**) or pasture (**PAST**) on cow performance and reproduction as well as calf performance and behavior through the feedlot receiving. Simmental × Angus (2 yr; 108/yr; 81 ± 15.3 d postpartum) spring-calving cows were stratified by age, body weight (**BW**), body condition score (**BCS**), and calf sex and allotted to six groups/yr. Groups were randomly assigned to 1 of 2 treatments: DL or PAST. Cows in DL were limit-fed at maintenance and calves had ad libitum access to the cow diet in an adjacent pen. Pairs on PAST were rotationally grazed and calves received creep ad libitum three weeks prior to weaning. On d 110 calves were fence-line weaned and behavior was observed on d 111 and 112. On d 116 calves were transported 272 kilometers to a feedlot for a 42-d receiving period. Behavior was evaluated again on d 117 and 118. Data were analyzed using the MIXED procedure of SAS except reproductive data which was analyzed using the GLIMMIX procedure. Cows on DL had greater BW ($P \leq 0.01$) at mid-summer and on d 110. There were no differences ($P \geq 0.16$) detected in BCS or reproductive data. Cows on DL tended ($P = 0.09$) to have greater milk production. Calves on DL had greater BW ($P = 0.01$) on d 55 and d 110 and greater ($P = 0.01$) preweaning average daily gain (**ADG**). There were treatment × time effects ($P = 0.01$) for lying and eating on d 111 and 112. More DL calves were eating in the morning and lying in the evening. More ($P < 0.01$) PAST calves were walking on d 111. Pasture calves vocalized more ($P \leq 0.01$) on d 112. Pasture calves had greater dry matter intake during the fence-line wean. On d 117, more ($P \leq 0.05$) pasture calves were lying and eating, and DL vocalized more. On d 118, treatment × time and treatment effects were detected ($P \leq 0.02$) for lying and walking. More PAST calves were lying and more DL calves were walking. Drylot calves had greater ($P \leq 0.02$) BW on d 116, d 137, and d 158. Pasture calves had greater ($P \leq 0.01$) ADG and gain to feed during feedlot receiving phase. In conclusion, housing cow-calf pairs in drylots improved BW and milk production of cows but did not affect reproductive performance. Drylot calves had increased BW and ADG during the preweaning phase. Calf behavior at weaning and receiving was influenced by preweaning housing. Pasture calves had improved receiving phase ADG and feed efficiency but were still lighter than drylot calves after 42 d receiving phase.

DEDICATION

To my family, thank you for instilling a burning passion for the livestock industry in me at a young age and always supporting my dreams.

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CHAPTER 1

LITERATURE REVIEW

INTRODUCTION

The beef cattle industry traditionally relies on the use of land that is unsuitable for crop production to maintain the cow herd. However, a decline in available natural resources, expansion in urbanization, and the conversion of pasture to cropland has led to the need for alternative management practices for cow-calf producers, specifically, in the Midwest. When costs to purchase or lease land are compounded by temporal or regional drought conditions, it can be challenging to secure the dietary needs of a traditional beef cow-calf enterprise. Fortunately, the Midwest is the prime location for growing the majority of the United States cereal grains. Thus, a wide variety of feedstuffs are often readily available. These feedstuffs can easily fulfill a cow's nutrient requirements at a less expensive price than pasture when considering land prices. Thus, producers are considering housing cattle in a drylot and feeding them these lower-cost feedstuffs as opposed to maintaining cows on pasture. Partial or total confinement management systems have seen greater interest over the recent years, especially during the winter months. While a drylot system has been successful in the winter months, there are limited studies on housing cow-calf pairs in a drylot during the summer months. This review explores what has been established in a traditional cow-calf system and then explore current literature on housing cows in a drylot or confinement system.

TRADITONAL COW-CALF SYSTEM

Traditionally, the conventional cow-calf system is characterized by maintaining cows on pastures and supplementing with required vitamins and minerals. The determination of a successful system is dependent on the availability and quality of the grass throughout the year (Ball et al., 2007). Grazing is generally the most cost-effective way to meet the nutritional needs of a cow (Mulliniks et al., 2015). The grazing system has had major improvements and developments over the years to maximize pasture use and cattle efficiency to maximize producer's income. Such advancements include rotational grazing, stockpiling forages, and grazing crop residue to aid in extending the grazing season.

Utilizing pasture/grazing systems

Rotational grazing systems have resulted in greater persistence of forages and herbage that is more digestible and contained more calcium, copper, and crude protein (Walton et al., 1981). This is a form of controlled grazing where a pasture is divided into paddocks. Cattle are rotated through the paddocks to maximize forage availability and allow for regrowth. Resting grazed paddocks allows the forage plants to renew energy reserves, rebuild vigor, deepen their root system, and give long-term maximum production (Undersander, 2002). When comparing continuous grazing to a 6-paddock and 11-paddock rotational grazing system, Bertelsen et al. (1993) reported that rotationally grazed pastures had greater stocking rates. Additionally, they found that gain per hectare was 40% greater for 6-paddock and 34% greater for 11-paddock treatments (Bertelsen et al., 1993).

Stockpiling pastures or harvesting and storing forage for the winter months is a common and vital practice amongst producers in the Midwest. Hitz and Russell (1998) conducted a 3-yr study to compare the performance of cows grazing either stockpiled forages or corn crop residues to being maintained in a drylot. The treatments were 1) strip-grazed stockpiled tall fescue-alfalfa, 2) strip-grazed stockpiled smooth bromegrass with or without red clover, 3) strip grazed corn-residue, or 4) confined in a drylot for 129 to 141 days with access to grass-legume hay. They found that cows grazing stockpiled tall fescue-alfalfa had greater BW gains compared to cows in other systems. Cows grazing pasture also required less kg of hay/cow when pasture was no longer available due to weather compared to cows on crop residue or in the drylot (Hitz and Russel, 1998).

Grazing corn residue has the potential to be an economical feed source for beef cattle (Klopfenstein et al., 1987). Since a large portion of livestock producers in the Midwest are also involved in grain production, this can be a great alternative. The best time for cows to graze cornstalk fields is right after grain harvest. Summers et al. (2014) studied post-weaning heifer development systems and their effect on performance and subsequent adaptation to grazing corn residue as a pregnant heifer. Heifers were randomly assigned to graze either winter range or graze winter range and corn residue. Although heifers on corn residue tended to have reduced ADG and BW compared to those grazing the winter range, there were no differences amongst treatments for heifers attaining puberty or pregnancy rates. As pregnant heifers, however, winter range heifers tended to have reduced ADG compared to heifers grazing corn residue. There were no differences amongst treatments for calving date, dystocia score, or calf birthweight between treatments.

Factors affecting nutritional requirements

Maintenance energy expenditures vary with body weight, breed or genotype, sex, age, season, temperature, physiological state, and previous nutrition (NASEM, 2016). Thus, there are many considerations when evaluating the needs of a cowherd and each can vary with differences in environments. When the cow begins lactating, her energy demands are the greatest. An average of available data indicate maintenance requirements of lactating cows are 20 percent greater than those of non-lactating cows (NASEM, 2016). Peak lactation is estimated to be around 50 to 65 days postpartum (Jenkins and Ferrell, 1984). After peak lactation, the requirements decrease until the calf is weaned. Then, the requirement for a gestating cow is considered the lowest during the production cycle (NASEM, 2016).

When considering nutritional requirements for cattle in a drylot versus pasture, a major difference between the two is the activity increment. According to NASEM (2016), it is highly probable that grazing cattle walk considerably farther than penned animals and thus grazing animals consequently expend energy. Brosh et al. (2006) monitored grazing cattle activity with motion sensors and GPS collars and found that grazing time ranged from 4.4 to 12.4 hours. The findings suggested that the cost of grazing activity is estimated to be 6.14 J/(kg of $BW^{0.75}$*m). When free-ranging heifers grazed crested wheatgrass rangeland they had a 46% greater energy requirement compared to stall-fed heifers (Havstad and Malechek, 1982).

A key management practice that helps producers asses the nutritional status of their herd is body condition score (Richards et al., 1986). Body condition score (BCS) is a method of categorizing breeding animals by their degree of body nutrient reserves. It is based on a 1-9 scale with 1 being severely emaciated and 9 being very obese (NASEM, 2016). In doing so, thin cows can be sorted from more fleshy ones and diets can be adjusted accordingly. It is recommended that mature cows enter the calving season at a BCS of at least 5 but not more than 7 (NASEM, 2016). Research has shown that evaluating BCS at weaning and breeding are important to potentially adjust the body condition score to initiate a new cycle in adequate condition (D’Occhio et al., 2019).

The relationship between nutrition and body condition score to reproductive performance in postpartum beef cows has been heavily studied. Studies have concluded that BCS at calving is arguably the most important factor in regards to a timely return to the estrus cycle and fertile ovulations for the next breeding season (D'Occhio et al., 2019). Cows with moderate to good BCS at calving can undergo a decline in BCS as they go through lactation, yet have a greater conception rate than cows who calved in poor BCS. Cows with a BCS of >5 at calving also tend to wean heavier and healthier calves (D'Occhio et al., 2019)

Breeding season

The day of breeding is the most important day of a cow's production cycle as it determines the rest of the production cycle for the year. If the cow is not breeding, the rest of the production cycle is irrelevant. Bellows et al. (2002) evaluated the cost of reproductive diseases and conditions estimated from the USDA National Animal Health Reporting System and found that the yearly cost of female infertility and reproductive diseases is $441 to $502 million for beef producers. Thus, reproductive failure is a major source of economic loss in the beef industry. Therefore, the goal of any breeding program no matter the type of service (artificial insemination or natural service) is to maximize the number of females that become pregnant (Perry et. al 2011). Fertility plays the largest role in success in a breeding program and is influenced by many factors. It is important that fertility in both the male and female are evaluated to ensure a successful breeding season (Perry et. al 2011).

While fertility in the cow is a main driver of reproductive success, a bull's libido and reproductive performance is equally important. A bull's libido is a highly inherited trait with heritability ranging as high as 0.59 (Chenoweth, 1997). For successful use of artificial insemination of cattle, the producer is responsible for detecting standing estrus to determine the proper time for cows/heifers to be inseminated. This can be mitigated through many protocols developed to aid in estrus detection and estrus synchronization. Estrus synchronization is important because it involves the manipulation of estrous cycles of heifers/cows causing them to exhibit standing estrous around the same time (Perry et al., 2011).

The implementation of applied reproductive technologies such as artificial insemination, estrous synchronization, and embryo cryopreservation into production systems has enhanced production efficiency (Lamb et al., 2016). Synchronizing the cowherd can shorten your calving season, produce more uniform calf weights, and provide the opportunity to use proven genetics through artificial insemination. Such synchronizing protocols involve either hormone injections or feed additives. There are a number of estrus synchronization programs available with various hormones including progesterone, prostaglandin, estrogen, and gonadotrophin releasing hormone. Ultimately, these programs can help shorten the calving season.

Calving season

It is general practice for producers to match their calving season to the time that they have access to ample feedstuffs to meet the nutritional demand of the cow and calf. It is estimated that approximately 60% of the calves in the United States are born from February to April, this period is referred to as the spring-calving season (NASEM, 2016). A shorter breeding and calving season generally results in increased calf production and greater efficiency. Calves born early in the calving season have greater body weight at weaning due to their older age and faster pre-weaning rate of gain (Lesmeister et al., 1973). Contrary to those findings, Deutscher et al. (1991) found in a 5-year study that there were no differences in weaning weights of calves from cows in early and late herds based off the length of the breeding season (30, 45, or 70 d in length). In this study, however, these results were expected because average calving dates were similar among groups in a calving herd, even though lengths of breeding seasons were different.

A calf's weight at weaning can be affected by a multitude of factors including genetics, environment, and nutrition.

INTENSIFIED COW-CALF SYSTEM

Now that the traditional cow-calf system has been discussed, the focus shifts to what is incorporated in an intensified system. Historically, cow-calf production in confinement has served as a useful alternative during times of limited pasture availability or when forage quality declines in the winter months (Miller et al., 2007). Yet as availability of grazing land for beef cattle is diminishing across some parts of the country, these systems are becoming more common. A multitude of factors contributes to this trend including conversion of pasture to cropland, drought, urbanization, and environment regulations. This shift in cow management has occurred primarily in the intensively cropped areas of the Midwest. A "drylot" is defined as a feedlot environment that is designed for feeding confined cow-calf pairs (Lardy, 2017).

Lardy (2007) posed a number of advantages associated with management in drylot settings including: increased marketability of crop residues, forages, and other feedstuffs, more control of the herd for health and management, easier synchronization and artificial insemination, and can lead to potential increased beef production per unit of land. Overall, a confinement system can provide more flexibility to an operation. These systems have traditionally been used to adjust what is fed to the cow as it allows producers to sort off thin cows from the group and adjust BCS accordingly. Additionally, it has been used as cows approach parturition and to aid in managing them during the post-calving stage (Miller et al., 2007).

Housing cows in a drylot during the winter months

The idea of housing cows in a confinement system during the months leading up to and during the calving season is fairly common in the Midwest. This confinement option provides better opportunities to monitor and provide assistance to cows during parturition (Gunn et al., 2014). This allows cows to calve in a dry, more temperature controlled environment which can decrease calf morbidity. Gunn states that 80% of calves lost at birth are "normal" but likely die due to delayed calving, dystocia, or hypothermia which can have a significant monetary impact. Whittier et al. (2009) reported that dystocia is responsible for 33% of all calf losses and 15.4 % of beef cattle breeding losses. A 3-year study summary of observational data from Anderson et al. (2013) described differences in cow-calf production types of confinement or pasture. The study reported an increase in dystocia occurrences for cattle in confinement vs cattle on pasture (14% vs. 5.3%, respectively) but did not report as to why there was a difference.

In addition to providing a dry, warm environment for the calf, cows can also benefit from drylot housing in regards to effectively managing energy requirements. Winter energy requirements of spring calving beef cows are influenced by the environment. Depending on the cow's BCS, energy requirements can be influenced greatly by cold weather. Cows in fatter condition typically have lower winter energy requirements than cows in thinner condition because of the insulation value of fat and its low maintenance requirement (NASEM, 2016). Thompson et al. (1983) found that fatter cows of Angus-Hereford breeding had 6.1% lower energy requirements than thin cows of the same breeding. Maintenance energy requirements of fat was -1.55 kcal ME/kg for Angus-Hereford cows, indicating that for cows of similar lean body mass, cows with more fat have a lower daily energy requirement during winter (Thompson et al., 1983).

Limit-feeding feedstuffs

When cows are maintained in drylots it is important to note that all nutrients consumed by the cow must be either stored or purchased feeds. Ever-changing hay and grain prices have led to inclusion of corn coproducts into drylot rations. Shike et al. (2009) found that when matching corn coproducts with low-quality crop residues, they can be very effective in maintaining lactating beef cows. Additionally, Loerch (1996) also found that corn-based diets have been proven as a viable alternative to feeding hay. Not only did Loerch (1996) find that this alternative resulted in meeting nutritional requirements but also suggested that feed costs may be reduced by up to 50% when using corn as an alternative energy source to hay. Corn can be a low-cost option but can fluctuate due to changes in prices through various seasons and years.

In addition to corn, corn byproducts have also served as a feed source to meet nutritional requirements. The most common feed byproduct produced today in North America is distillers grains plus solubles (NASEM, 2016). Distillers are a great source of protein in ruminant diets as they are a more concentrated source of protein compared to corn. When they are fed at 15 to 20% of the diet, they can also be considered a great energy source (Klopfenstein et al., 2008). The inclusion of co-products (such as distillers) to limit-feed cows during lactation can reach 75% of the diet without detrimental effects (Shike et al., 2009). When comparing the influence of late gestation drylot rations differing in protein degradability and fat content on beef cow and subsequent calf performance, Wilson et al. (2016) reported that cows' limit-fed corn coproducts and ground cornstalks had greater BW and BCS compared to cows limit-fed ground hay. Feeding these coproducts could potentially be less expensive than purchasing forages or pasture ground.

Costs to maintain the cowherd are responsible for over 60% of the beef producers' annual costs (Miller, 2002). Thus, it is important to use feedstuffs that are readily available and relatively inexpensive. Braungardt et al. (2010) investigated the effects of a winter feeding strategy on the performance, lactation, reproduction, and feed costs of spring-calving, lactating beef cows. Three-year average price data was used to calculate feed costs for corn residue, DDGS, and hay. They found that the hay diet was more expensive than the DDGS and corn residue diets ($2.50 vs. $1.44/cow/day). It was concluded that feeding corn coproducts with corn residue bales can results in acceptable performance and reduced feed costs compared to traditional hay diets (Braungard et al., 2010).

In another study conducted by Lalman et al. (2014), Angus and Angus x Hereford cows were utilized to compare an extensive pasture system to an intensive partial-confinement system. Cow-calf pairs allotted to the extensive system were on native rangeland and provided protein supplement to meet requirements whereas pairs in the intensive system were provided hay and mineral supplement. Additionally, intensive treatment cows were allowed unlimited access to wheat pasture. They found that cows in the extensive system lost more weight compared to cows in the intensive system who maintained body reserves more effectively through weaning. Annual costs per cow/calf pair were estimated to be $95.63 greater for the intensive-raised system. However, intensive-raised calves gained more and had greater weaning weights which resulted in an additional $69.56 in calf value (Lalman et al., 2014).

Loerch (1996) found that when cows were limit-fed they showed behavioral signs of hunger even though they had a caloric intake similar to that of cows fed hay free-choice (approximately 14 Mcal of NEm per day). The authors speculated this could be explained by a difference in visceral organ mass (Loerch, 1996). Restricted feeding or limit feeding results in reduced visceral organ mass compared with offering feed for ad libitum consumption in lambs (Fluharty et al., 1997).

Additional advantages related to limit feeding include reducing waste. When access to hay fed ad libitum with no restrictions was compared to restriction times of 9, 6, or 3 hours per day in Miller et al. (2007), hay waste increased linearly with increasing time of access. Cows on each treatment gained BW and maintained acceptable levels of cow performance even with the differences in time of intake. Similarly, Cunningham et al. (2005) conducted a study where pairs were permitted limited access to hay ring feeders for 4 or 8 hours or given 24-hour access per day. There was a tendency for cows having longer time access to hay to have greater BW, however there was no difference in calf performance.

If hay must be fed ad libitum, the type of feeder is a large factor in reducing hay waste. Landblom et al. (2007) found that feeding bales in a tapered-cone round bale feeder increased cow weight gain, tended to increase rib fat depth, and reduce hay consumption by an average of 10.2% compared with rolling bales out on the ground or using a bale processor to shred hay on the ground. Additionally, the amount of bunk space for a TMR is equally important in reducing waste. Researchers recommend 0.6 m per cow for adequate linear feed bunk space (Grant and Albright, 2001). When designing a new facility, it is also important to factor the size of the bunk so that given the opportunity to use residues and coproducts, more bulky rations can be offered (Jenkins et al., 2015).

Health and animal welfare

The design of a drylot system can impact the herd’s health and overall well-being (Lardy, 2017). Drylots can be a hot, crowded, muddy, dusty or even fly-infested environment. Thus, a well-drained or paved site with a southern exposure and periodic manure removal reduces environmental stress (Lardy, 2017). Cattle in confinement systems are by default more crowded and have the potential for more transmission of disease, an increased likelihood of injury, and have a greater concentration of manure (NASEM, 2016). Another factor that should be considered is animal density as it can result in rapid disease transmission (Lardy, 2017). One of the major factors that should be considered in drylot scenarios is hoof health. When considering housing cows in a confinement setting, there is a lot to learn from the dairy industry in regards to ways to prevent lameness and prevent hoof problems. Majority of the research regarding cow lameness has been done in dairy.

Hoof health

Hoof health is crucial in any operation not only to ensure animal welfare but also animal performance. If a cow is experiencing lameness, they will likely not be making many trips to the bunk which can lead to a cascade of problems. There are many diseases that affect hoof health that cattle producers fight each year. Two common hoof diseases are foot rot and digital dermatitis. Foot rot is a common disease that can cause lameness and a decrease in weight gain (Currin et al., 2009). This disease is primarily caused by the bacteria *Fusobacterium necrophorum* which is an anaerobic bacterium. Unfortunately, this bacterium is commonly found in the environment and other bacteria can increase the virulence and incidence of *Fusobacterium necrophorum*. It is estimated that foot rot accounts for 75 percent of all lameness diagnosed in cattle. The most common treatment for foot rot is a long-acting tetracycline such as LA-200. Inclusion of zinc in the diet is also important to maintain the integrity of the skin and hoof (Currin et al., 2009).

Another disease that is a common vector to lameness is digital dermatitis otherwise known as hairy heel wart. It begins as a small lesion between the bulbs of the heel. As it progresses, the tissue overgrows dermal tissue and keratin which makes it look like hair. This results in lameness in the cow as it is painful to put weight on the infected area. This disease is more commonly found in adult dairy cattle in confinement but with the increase in beef cattle now in confinement it has become more of a problem in beef cattle. (Plummer and Krull, 2017) The most common treatment is to topically treat with oxytetracycline soluble powder or tetracycline powder and to wrap the foot with a light bandage (Plummer and Krull, 2017). In an evaluation of 43 infected cows that were observed for 50 days after treatment, 93% of cows had improvement in the lesion score but only 9% of them returned back to normal skin (Plummer and Krull, 2017). Both of these diseases can have a big impact on producers due to a decrease in intake in addition to the cost and labor to treat.

WEANING STRATEGIES

Under natural conditions, when milk yield from the dam begins to decrease is the time that the weaning process takes place. Natural weaning in cattle occurs between 7 and 14 months of age, yet the cow-calf dyad maintains some proximity some months following the end of suckling (Reinhardt and Rainhardt, 1981). In contrast, in most management systems weaning occurs at 6-7 months of age (Enríquez et al., 2011). Weaning involves separating the cow and calf so that the calf begins to shift its intake from milk to solid feed. This shift in intake and change of environment can result in both behavioral and physiological indices of distress in cattle (Lefcourt and Elsasser, 1995). Over the years, many weaning strategies have been evaluated to aid in decreasing the stress put on the calf. These techniques have decreased in the incidence of calf morbidity and increased performance and intake.

Abrupt weaning

Abrupt weaning is the most common weaning method in conventional cow-calf systems (Enríquez et al., 2011). In this system, weaning typically occurs earlier than the natural process. Under normal conditions, this system weans when peak lactation is over and calves are ready to graze and ruminate between five and eight months of age. After cows and calves are separated, calves are usually taken to a new location. This new location can be a feedyard or to another farm to be backgrounded. This scenario does not allow the dam and calf to have any sort of contact (Enriquez et al., 2011). This method of weaning is common amongst producers since it is the least labor-intensive.

Two-stage weaning systems

A method known as fence-line weaning has been developed as another strategy to minimize negative effects at weaning. This two-stage method allows cows and calves to see and hear each other, but a fence is separating them so that the calf cannot nurse. This fence-line separation happens over the course of a couple days to a week. To some producers, this method is not practical due to a lack of pens and a sturdy fence to withhold cows and calves trying to get to one another. Price et al. (2003) found that when calves were fence-line weaned for seven days, they spent more time grazing or eating hay compared to calves that were abruptly weaned. In addition, the fence-line weaned calves vocalized less when the groups were commingled. Fence-line weaned calves also gained 95% more when the groups were commingled and had a performance advantage throughout the rest of the study (Price et al., 2003). In agreement, Boyles et al. (2007) also found fence-line weaning as a great strategy to minimize stress for calves entering the feedlot. Not only did the fence-line weaned steers have an advantage in ADG but also had a decreased incidence of morbidity compared to abruptly weaned calves.

Another two-stage weaning system that has been developed is the use of nose flaps. This plastic nose flap device prevents nursing by providing a physical barrier between the calf's mouth and the cow's teat. Yet, the device does not interfere with the calf's ability to graze, eat creep, or drink (Haley et al., 2005). This method has seen a lot of attention in recent years. Haley et al. (2005) evaluated behavioral responses of calves weaned with these nose-flaps versus calves weaned by abrupt separation to explore the possible benefits of using a two-stage weaning method in regards to ADG and behavior. Calves weaned in two stages vocalized and spent less time walking compared to calves weaned abruptly. They also spent more time eating and resting compared to calves weaned abruptly. However, overall calf ADG did not differ for either treatment in the study. In contrast, Lippolis et al. (2016) evaluated the effects of nose flap weaning devices on cow and calf performance before and after separation from the dam, and calf humoral immune response. Cow-calf pairs were allocated to 1 of 2 treatments 1) nose flap for 21 d before separation from the dam or 2) no nose flap for 21 days before separation from the dam. Control calves tended to have greater BW on d 14 and 21 than nose flap calves, and control calves had greater ADG from d -21 to 1 compared to nose flap calves. Treatments did not differ for post-weaning DMI, G:F or morbidity however. Yet, preweaning ADG, serum BVDV-1 and BHV-1 titers, and humoral immune response to OVA were decreased in calves that were weaned with a nose flap (Lippolis et al., 2016). A similar study was conducted by Rauch et al. (2018) where nose-flap devices were inserted for comparing two-stage weaning to abrupt weaned calves. Calves weaned in two-stages had decreased behavioral signs of stress at weaning but also had decreased ADG pre-weaning.

Early weaning

Aside from abrupt and two-step weaning methods, there is also the ability to early-wean. As mentioned earlier, it is recommended to match the calving season with when cows will have access to high quality diets to ensure lactation and consequently milk production for the calf. While it would be ideal for every producer to be able to accomplish this, it is not always an option for some. Thus, the ability to early-wean can positively affect both the calf and dam. Studies have shown that beef calves can be weaned at 3 to 4 months of age without causing feeding or management problems (Peterson et al. (1987). Peterson et al. (1987) evaluated performance of fall-calving cows and their progeny when calves were weaned at 110 or 222 d of age and determined the economic advantage of weaning at 110 d. Early-weaned calves were 25.2 ± 4.4 kg heavier at normal weaning and gained 29.0 ± 3.0 kg more from early to normal weaning than normal-weaned calves. Cows with early-weaned calves consumed 45.3% less hay on a total digestible nutrients basis, than cows with normal-weaned calves. In total, early-weaned cow-calf pairs were 43.0% more efficient in converting total digestible nutrients into calf gain than were normal weaned cow-calf pairs (Peterson et al., 1987)

Additionally, Myers et al. (1999) conducted a study looking at early-weaning vs. normal weaning calves in addition to supplementing with or without creep and the effects on carcass characteristics. In the feedlot, early-weaned calves had lower intakes but better feed conversions. Marbling score was also improved for early-weaned steers. Similarly, in Meteer et al. (2013) marbling score was greater for early-weaned calves when compared to creep-fed calves (586 vs 500). Early weaning and creep feeding increased carcass quality and growing-phase BW but reduced profits (Meteer et al., 2013).

Creep Feeding

There are many factors that can go into the survival and development of a weaned calf, but one of the main factors is the calf's nutrition. The maternal environment provided by the calf's dam is a major driver of this (Clutter and Niesen, 1987). Interestingly, at birth, the calf is considered a non-ruminant because the rumen is yet to be functional. The young calf relies entirely on milk for its nutrients for the first couple weeks of life. Milk is digested by the calf's enzymes in the abomasum and small intestine. The esophageal groove forms a passage between the esophagus and omasum to ensure the passage of milk goes directly into the abomasum without entry into the reticulorumen (Drackley, 2008).

The beef industry has learned a great deal from the dairy industry with regard to transitioning calves to feed. In dairy production, it's common to introduce feed at a younger age due to earlier separation from the dam. As the dairy calf begins to consume starter feed, the calf moves into what is called the second or transitional phase which lasts until the calf is weaned. During this phase, as starter feed is consumed, fermentation in the underdeveloped reticulorumen leads to expansion and differentiation of the rumen epithelium so that volatile fatty acids (VFA) are produced from microbial fermentation. The final stage is the ruminant phase, which begins at weaning and lasts the remainder of the animal's life. The ruminant will depend on fermentation of dietary carbohydrates for most of its energy in the form of VFAs. Dietary proteins, bypass proteins, dietary carbohydrates and fats supply the remaining protein and energy required (Drackley, 2008).

Clutter and Nielsen (1987) looked at the effects of milk production differences on calf growth traits in the absence of differences in cow size and growth rate potential. Calves suckling high milk-group dams had 16.9 kg greater 205-d weaning weight than those suckling low milk-group dams. Additionally, calves in the high-milk group maintained 63% of the advantage over those in the low-milk group in 205-d weight through a post-weaning growth period to slaughter. Similarly, Jenkins et al. (1991) concluded that cows with greater milk weaned heavier calves. However, more feed was required to maintain the body weight and thus was considered less efficient.

Another benefit of creep feeding entails the ability to alleviate nutrient deficiencies associated with drought conditions or forage shortages. This can lead to a greater economic return for producers but should be evaluated on a year-to- year basis (Lardy and Maddock, 2007). Creep feeding can also alleviate nutrient stress of the dam and in turn allow her to breed back sooner (Stricker et al., 1979). The cow dedicates her energy to lactation to sustain her current calf at side, but once she is re-bred she also dedicates to the developing fetus (Freetly et al., 2006). Thus, the removal of the calf immediately lowers the dam's energy requirements shifting from lactation to maintenance (NASEM, 2016)

Most creep feeds can be classified into three broad classifications including energy-based creep feeds, protein-based creep feeds, and forage-based creep feeds (Lardy and Maddock, 2007). Generally, limit-fed, high-protein creep feeds are more efficient, and gains may be similar to calves offered energy-based creep ad-libitum. These high-protein creep feeds contain crude protein levels of at least 25%. Energy-based creep feeds contain 12-18% crude protein and are generally offered free choice. These protein-based and energy-based creep feeds are generally the most available in the United States. Forage-based creep feeds incorporate high quality forage, pasture, or range through specialized fencing so that the dam cannot have access. While this practice is not as common in North America it can be when producers have access to small, high quality pastures (Lardy and Maddock, 2007).

In regards to the proper length of time to feed creep, the timing can vary depending on the operation. In a comparison of feeding creep for 28, 56, or 84 days it was found that feeding for 56 or 84 days improved gain, but 56 days had the most efficient supplemental gain. Creep feeding for 28 days showed no advantages during the creep feeding period or in the feedlot (Tarr et al., 1994)

Historically, creep feeding beef calves has consistently improved weaning weight of beef calves (Faulkner et al., 1994), developed the rumen (Drackley, 2008) and created a smoother transition to consuming feed when weaned. Additionally, creep feeding has shown effects not only during the suckling phase but also on post-weaning performance, carcass characteristics, and impacts on cow performance (Tarr et al., 1994). The effect of the creep feed impacted not only the performance in finishing phase but also improved the carcass weight (18.5 kg) and ribeye size (4%) in Angus × Simmental steers (Shike et al., 2007). When creep-fed calves were followed through the finishing phase in Meteer et al. (2013) they gained 9% more, had 7% lower DMI, and were 16% more efficient than early-weaned calves. Deutscher and Slyter (1978) found that creep-fed calves exhibit greater marbling scores and quality grade than non-creep fed calves. However, most research does not show differences in quality grade or marbling score when creep-fed calves are compared with non-creep calves (Tarr et al., 1994; Myers et al., 1999).

Behavior at weaning

As stated previously, weaning is the most stressful time in a calf's life. The separation from its milk supply and dam is a big change and can create a lot of stress on the calf. This stressful event can be evaluated by looking at the behavioral signs of stress the calf exhibits. The immediate responses to abrupt weaning are predictable and occur for several days after separation (Haley et al., 2005). In Haley et al. (2005), calves were fitted with an anti-sucking device for either 14 d or 3 d before separation compared with control calves who were not fitted with a device. Two-stage weaned calves spent 78.9% less time walking, 23.0% more time eating, and 24.1% more time resting compared to control calves. Differences amongst the treatments were the greatest in the first two days prior to separation. Overall, calves weaned in two-stages were less distressed than calves that were weaned abruptly (Haley et al., 2005). Similarly, Stookey et al. (1997) found that in the first 2 days after weaning, abrupt weaned calves spent more time walking and less time eating and lying compared to fence-line weaned calves. In agreement, Rauch et al. (2018) found that a two-step weaning system decreased the percentage of calves walking and standing compared to abrupt weaned calves. The two-step weaning system also had an increase in the percentage of calves lying (Rauch et al., 2018).

Price et al. (2003), studied the behavior of calves at weaning when calves were abruptly weaned, fence-line weaned, and not weaned. Within the abruptly weaned treatment, they also had a pasture and drylot group. They looked at the behaviors of eating (grazing or eating hay), walking, lying down, vocalizing, and in the fence-line groups they measured proximity of calves and cow to the fence separating them. They also looked at the proximity of cows and calves in the control-pasture group. Over this three-year study, they found that in the days following weaning, the fence-line weaned calves spent more time eating than both groups of abrupt weaned calves. The fence-line weaned calves also spent more time lying down and exhibited fewer vocalizations than abruptly weaned calves. The abrupt weaned pasture calves spent more time walking than calves in any of the other treatments (Price et al., 2003).

Vocalization

Vocalizations in domesticated livestock have been known to be an indicator of stress, especially in cattle and pigs (Warris et al., 1994). Cattle emit vocalizations that are likely meaningful to other cattle, but we cannot interpret a meaning behind them. There is limited research regarding the meaning behind vocalizations in beef cattle but studies have the potential for useful implications for animal production and welfare.

At weaning, a common way the cow and calf both exhibit stress is through vocalizations mostly known as bawling. These vocalizations may convey specific information about the experiences of the animal concerned (hunger, isolation, separation, fear, etc.; Watts et. al., 2000). It has been documented that calves are able to discriminate a played-back recording of their own mother's voices from the voices of other cows. Yet there has been no comparable evidence that cows can recognize their calves by sound (Watts et. al., 2000).

Stěhulová et al. (2017) conducted a study evaluating the cow and calf's reaction to weaning. Based on the theory of maternal care allocation that females respond more to weaning, they hypothesized that cows weaning a heavy, young, female calf would respond more at weaning through vocalizations. To evaluate this, they recorded frequency of vocalization and time spent moving in 50 cow-calf pairs recording in two-hour increments up to 26 hours after separation. In cows, the age of the calf had the strongest effect with mothers of younger calves vocalizing more. The authors speculate that this is due the mother-young bond weakening as the calf is older and becomes more independent. Frequency of vocalizations was greater in dams with calves of greater daily weight gain. They speculate that this is due to those cows having greater milk output and thus the bond could have been stronger. There were no differences in cows regarding the sex of the calf, however female calves vocalized and moved more than males. Calves with greater daily weight gain also vocalized more. The authors speculated that this is due to greater milk supply and more frequent nursing, thus they were more dependent on their dam for nutrient supply (Stěhulová et al. 2017).

In Haley et al. (2005), abruptly weaned calves averaged 41.9 calls/h which was approximately 30 times greater than calves weaned in two-stages. Price et al. (2003) also found that fence-line weaned calves exhibited fewer frequencies of vocalization compared to abruptly weaned calves in the first 3 d following separation. Similarly, Stookey et al. (1997) reported that fence-line weaned calves vocalized less in the first 2 days post weaning compared to abrupt-weaned calves. Calves weaned in two-steps with nose-flap devices also vocalized less 2 d post weaning in Rauch et al. (2018).

RECEIVING PHASE

Upon arrival to the feedlot environment there are many stressors that may be imposed on the calf. They may have to acclimate to manure, mud, poor air quality, and are exposed to a new social dominance and even new pathogens. Processing procedures upon arrival such as vaccinations, castration, and dehorning can also cause stress. These stressors can increase the incidence of morbidity and mortality, decrease performance, and tax the financial and labor resources of cattle producers. Overall, minimizing stress upon arrival and adaptation to the feedlot is crucial to producer’s bottom line (Loerch and Fluharty, 1999).

Hans Selye (1976) proposed that when animals are exposed to stress, they react in a three-step process called the *general adaptive syndrome*. The initial response to a stressor is called the alarm reaction. This is characterized by vocalization, an adrenal pituitary and hypothalamic response, and by catabolism. The second response is resistance. This stage is characterized by anabolism and increased feed intake. In feedlot cattle, this may not take place until 2 to 3 weeks after arrival (Hutcheson and Cole, 1986). If resistance is not successful, animals enter the last stage, exhaustion. This stage describes the situation in which adaptive capability is finite; exhaustion occurs before the animal is capable of adapting to the stressor (Seyle, 1976).

Commingling

When weaned calves from various sources are commingled there is an increased risk of disease outbreak due to weakened immune systems from stress and the exposure to new pathogens. As newly arrived feedlot calves enter the feedlot they undergo numerous stressors that result in transient endocrine responses, altered products of energy and protein metabolism, changes in appetite and growth rate, limited compromise of digestive and rumen function, and a challenged immune system (Loerch and Fluharty, 1999). Many times, commingling is perceived as an acute or chronic stressor to cattle depending upon how much time is required for social structures to reform and stabilize (Grant and Albright, 2001). Aside from calves getting adjusted to a new diet, commingling groups typically result in a new pen dynamic. When cattle from various sources are commingled in the same pen, social hierarchy is destabilized and psychological stress reactions are provoked until social structure is re-established (Loerch and Fluharty, 1999).

Another factor to consider when commingling groups of cattle is disease. The major disease that accounts for approximately 75% of total feedlot morbidity is Bovine Respiratory Disease (BRD; Wilson et al., 2017). This significant production problem costs the U.S. cattle industry over $500 million each year (Powell, 2013). Bovine Respiratory Disease is a viral and bacterial disease of the respiratory tract and is easily contracted amongst newly weaned calves with a suppressed immune system. Vaccinating against this potentially fatal disease is a great way for producers to increase immunity to pathogens (Wilson et al., 2017). Step et al. (2018) found an increase in BRD incidence in receiving pens containing steers of multiple sources compared to pens of steers from a single source. A recent study from Wiegand et al. (2020) found that commingling cattle from different sources did not impact performance, physiological responses, and BRD incidence during a 56-day receiving period, however the recurrence of BRD after a second antimicrobial treatment increased according to commingling level.

Adaptation

Coming into the feedlot, calves from different backgrounds were likely weaned using various methods. Thus, some may have been exposed to creep and are used to bunk feeding while others may have not. Preconditioning calves prior to marketing has proven to result in increased intakes during the feedlot receiving period. Management decisions to implement these strategies should be based on potential costs and benefits (Loerch and Fluharty, 1999). Poor adaptation to the feedlot is a stressor that delays the onset of bunk feeding in newly arrived cattle by a week or more in some cases (Hutcheson and Cole, 1986). In that study, they found that after 1 week in the feedlot there were still 5% of healthy cattle and 17% of sick animals that had not consumed any feed and 12% of healthy steers and 30% of those that were sick at the time had not yet established a daily feeding pattern.

One way to avoid this poor adaptation to the feedlot and better establish daily feed intake is by training cattle through yard weaning and yard training as described in Walker et al. (2007). In this study, they determined the effect of weaning in small yards with or without a feed bunk training procedure, on the subsequent behavior and performance of *Bos Taurus* steers in a feedlot. The treatments included (1) yard weaned with hay or silage, (2) yard weaning with hay or silage plus a novel handling procedure to train the animals to be able to find a grain ration in a trough, and (3) paddock weaning without supplement or handling according to common industry practice in southeastern Australia. They found that yard weaned and yard trained cattle had a significantly greater weight gain in the first month and over the first 90 days of the feeding period compared to paddock weaned groups. The yard trained groups also showed greater feeding activity during the first few days in the feedlot. However, they were not significantly different in weight gain from yard weaned (Walker et al., 2007).

Intake

Hutcheson and Cole (1986) found that newly arrived feedlot calves have low intake. They concluded that newly arrived feeder calves typically consume 0.5 to 1.5% of their BW during the first week and 1.5 to 2.4 % of their BW in the second week. Normal intakes are achieved between 2 and 4 weeks after arrival. Thus they suggested that post-arrival diets should contain a greater quantity of protein than the diet that cattle consumed before arriving at the feedlot. Another strategy to increase nutrient intake is to increase the nutrient density of the receiving diet to offset low feed intake. This strategy is used in the swine industry to increase the nutrient intake of early-weaned pigs (Hutcheson and Cole, 1986).

Diet

Diet plays a major role in calf's intake as they arrive to the feedlot regardless of if the calves have received creep or not. Fluharty et al. (1994) conducted a feedlot receiving experiment with newly weaned calves that had not been previously exposed to creed feed to determine the effects of energy density and protein source in receiving diets containing approximately 13% CP on steer performance. The factors compared were energy density (1.80 vs 1.48 mcal/kg of NEm), referred to as high-energy and low-energy, respectively. High-energy diets resulted in an 8.7% improvement in feed efficiency vs low-energy diets. (Fluharty et al., 1994).

Fluharty and Loerch (1996) conducted three experiments to determine the effects of energy source and level on performance of newly arrived feedlot calves. In the first experiment, the effects of receiving diet and previous creep feeding status on calf performance were determined. Diets were composed of either corn silage; a combination of corn silage, alfalfa pellets, and dry corn; or dry corn and alfalfa pellets. For the 41-d trial, calves fed the corn silage-based diet had greater ADG and feed efficiencies than the calves fed the other two diets. Their findings suggest that newly arrived calves at the feedlot initially prefer a diet that was similar in moisture and texture to feeds which they were familiar with prior.

Compensatory gain

As calves come into the receiving phase, they are likely coming in at different weaning weights and have been backgrounded on different planes of nutrition. Additionally, these calves are experiencing some sort of transportation stress which can as discussed, decrease intake (Hutcheson and Cole, 1986). Thus, the likelihood of calves to experience some form of compensatory gain is high. The phenomenon of compensatory gain is described as a period of faster or more efficient rate of growth following a period of nutritional or environmental stress. A major component of compensatory growth by animals given abundant feed after a period of restriction is increased feed intake (NASEM, 2016). An animal's ability to compensate following a period of underfeeding depends on the nature, severity, and duration of the restriction in addition to the age of the animal at the onset of the restriction and relative mature weight of the animal (Abdalla et al., 1998). Abdalla et al. (1988) conducted a study where Holstein steer calves 8 to 12 weeks of age were fed either a low level of protein, high level of protein, or an energy restricted diet for 154 days and then switched to a different diet for 98 days before finishing on a high-energy diet. Compensatory gain was observed in all restricted groups with growth rates 14 to 30% greater than controls. Degree of restriction altered the amount of compensatory gain and those that gained less during low protein feeding gained faster during recovery. The restricted groups required 12 to 117 more days to reach a similar percentage of final body fat to control steers (Abdalla et al., 1988).

CONCLUSION

It is well known that historically beef cow-calf producers have based their production systems on grazing pasture. As technologies and management strategies have evolved, extending the grazing system has been explored and many new systems have been implemented. However, as the price of pastureland will likely continue to increase in the future, exploring the efficacy of intensified production systems is crucial for Midwest producers. While the traditional system of grazing cows on pasture will still be a preferred and economically efficient system for most, studying the effects of these alternative systems are extremely important. It has been well documented that intensified systems such as a drylot can reduce costs by limit-feeding cows, enabling better monitoring and control of nutritional status, and allowing producers to better monitor cows calving. While drylots have proven to be a viable option during the winter months, there is still research needed in understanding the best methods for raising cows and calves in a drylot during the summer months and for extended periods of time. When cattle are confined in a smaller space it can result in increased disease and foot problems so it will be important to research these factors when considering housing cows and calves in a drylot during the summer months. Additionally, studying how to feed these calves and their performance during and after being raised in a drylot will be a driving factor for its potential use. Overall, with knowledge of proper management practices, the success of this type of production system will likely be more common in years to come.

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CHAPTER 2

EFFECTS OF HOUSING BEEF COW-CALF PAIRS ON DRYLOT OR PASTURE ON COW PERFORMANCE AND REPRODUCTION AS WELL AS CALF PERFORMANCE AND BEHAVIOR THROUGH FEEDLOT RECEIVING

ABSTRACT

The objectives were to analyze the effects of housing cow-calf pairs in drylots (**DL**) or pasture (**PAST**) on cow performance and reproduction as well as calf performance and behavior through the feedlot receiving. Simmental × Angus (2 yr; 108/yr; 81 ± 15.3 d postpartum) spring-calving cows were stratified by age, body weight (**BW**), body condition score (**BCS**), and calf sex and allotted to six groups/yr. Groups were randomly assigned to 1 of 2 treatments: DL or PAST. Cows in DL were limit-fed at maintenance and calves had ad libitum access to the cow diet in an adjacent pen. Pairs on PAST were rotationally grazed and calves received creep ad libitum three weeks prior to weaning. On d 110 calves were fence-line weaned and behavior was observed on d 111 and 112. On d 116 calves were transported 272 kilometers to a feedlot for a 42-d receiving period. Behavior was evaluated again on d 117 and 118. Data were analyzed using the MIXED procedure of SAS except reproductive data which was analyzed using the GLIMMIX procedure. Cows on DL had greater BW ($P \leq 0.01$) at mid-summer and on d 110. There were no differences ($P \geq 0.16$) detected in BCS or reproductive data. Cows on DL tended ($P = 0.09$) to have greater milk production. Calves on DL had greater BW ($P = 0.01$) on d 55 and d 110 and greater ($P = 0.01$) preweaning average daily gain (**ADG**). There were treatment × time effects ($P = 0.01$) for lying and eating on d 111 and 112. More DL calves were eating in the morning and lying in the evening. More ($P < 0.01$) PAST calves were walking on d 111. Pasture calves vocalized more ($P \leq 0.01$) on d 112. Pasture calves had greater dry matter intake during

the fence-line wean. On d 117, more ($P \leq 0.05$) pasture calves were lying and eating, and DL vocalized more. On d 118, treatment × time and treatment effects were detected ($P \leq 0.02$) for lying and walking. More PAST calves were lying and more DL calves were walking. Drylot calves had greater ($P \leq 0.02$) BW on d 116, d 137, and d 158. Pasture calves had greater ($P \leq 0.01$) ADG and gain to feed during feedlot receiving phase. In conclusion, housing cow-calf pairs in drylots improved BW and milk production of cows but did not affect reproductive performance. Drylot calves had increased BW and ADG during the preweaning phase. Calf behavior at weaning and receiving was influenced by preweaning housing. Pasture calves had improved receiving phase ADG and feed efficiency but were still lighter than drylot calves after 42 d receiving phase.

INTRODUCTION

Historically, cow-calf producers have maintained cow-calf pairs on pastures and supplemented them as needed to meet requirements. The availability and quality of grass throughout the year have been known to determine the success of a producer's system (Ball et al., 2007). Urbanization has caused an increase in land prices making pasture expensive and less available for producers. Additionally, Midwest farmland is made up of fertile soil which is ideal for crop production causing the conversion of pastureland to cropland to increase. Therefore, cattle producers are seeking an alternative system for housing cow-calf pairs. Researching alternative systems to pasture is important for cattle producers as production needs increase with the world population expected to exceed 9 billion by 2050 (United Nations, 2019).

Maintaining cow-calf pairs in a drylot system is not a new concept, drylots have proven to be an effective alternative when there is a shortage of forage availability (Thomas and Durham, 1964). Feeding cattle in drylots gives producers more flexibility to use low-cost feedstuffs such as corn or corn coproducts. These coproducts such as distillers grains or corn gluten feed, effectively meet energy needs during lactation (Shike et al., 2009) and even increase cow BW and BCS during gestation and lactation (Wilson et al., 2016). Energy requirements of beef cattle housed in drylots can be up to 20% less than cattle grazing pasture (Miller et al., 2007). Drylots are commonly used during the winter months in the Midwest. Over the years, they have provided advantages such as the ability to monitor cows during parturition (Gunn et al., 2014), and the dryer and less windy conditions can decrease maintenance requirements (NASEM, 2016). Additionally, drylots have the potential to increase the adoption of synchronization and aid in maximizing on artificial insemination and other technologies in systems where a working facility can be easily accessed (Lardy, 2017). Ultimately, a drylot system can provide producers flexibility of management.

Although drylot systems have proven to be a viable alternative during the winter months, limited research is available studying the effects of housing cattle in these systems during the summer months. Evaluation of impacts of these systems for extended periods on cow and calf performance in a long-term setting is needed. We hypothesized that cows housed in a drylot would better maintain body weight and body condition score compared with cows on pasture. Additionally, we hypothesized that calves raised in a drylot would be better adapted to a feedlot environment and display less behavioral signs of stress at weaning and feedlot arrival which would contribute to increased performance. The objective was to determine the effects of housing cow-calf pairs in a drylot compared to pasture on cow performance and reproduction, as well as calf performance and behavior at weaning and through feedlot receiving.

MATERIALS AND METHODS

All experimental procedures were approved by the Institutional Animal Care and Use Committee of the University of Illinois (Protocol #20083) and followed the guidelines recommended in the Guide for the Care and Use of Agricultural Animal in Agricultural Research and Teaching (FASS, 2010).

Animals, Experimental Design and Treatments:

To evaluate the effects of housing cow-calf pairs on drylots (**DL**) or pasture (**PAST**) on cow performance and reproduction as well as calf performance and behavior at weaning and through feedlot receiving, a 2-yr study with 216 spring-calving (81 ± 15.3 d postpartum), Angus × Simmental cows [body weight, (**BW**) = 659.4 ± 88.1 kg] and their progeny were evaluated at the Orr Agricultural Research and Demonstration Center (OARC) in Baylis, IL. Prior to the initiation of the study, cows calved on drylots and were limit-fed the same TMR described as TMR 1 for both years in Table 1.

A stratified, randomized design was used for this experiment. Cows were stratified by age, BW, body condition score (**BCS**: emaciated = 1; obese = 9; as described by NASEM, 2016), calving date, previous treatment, and sex of the calves and allotted to six groups each year. Groups were randomly assigned to 1 of 2 treatments: DL or PAST. Cows on DL were maintained in a 21.9 × 11 m concrete lot that allowed 13.4 m^2/cow with a 14.6 × 7.3 m shed allowing 5.9 m^2/cow. Their calves had access to an adjacent creep pen that was 11.0 × 11.0 m concrete lot with a 7.3 × 7.3 m open-front shed. The area under roof was bedded as needed during the treatment period with wheat straw.

Drylot cows were limit-fed a TMR formulated to maintenance (NASEM, 2016) in a 14.6 m concrete bunk allowing for 0.8 m/cow. There were 3 sequential TMR fed each year that consisted of corn silage, dried distillers grains, ground hay, ground stalks, corn, soybean hulls and mineral. There were minor year-to-year variations in the TMR due to ingredient availability. The TMR 1 in year 1 included ground hay whereas TMR 1 in year 2 did not. In both years, TMR 2 was fed until corn silage was no longer available. The TMR 3 replaced corn silage with soybean hulls, corn, and ground stalks. Calves in the drylot were fed the same TMR as cows' ad libitum in an adjacent creep pen with a 7.3 m concrete bunk allowing for 0.4 m/calf.

Cow-calf pairs on PAST were managed on a rotational grazing system stocked at 4.01 pairs/ha, animals were rotated biweekly. Pastures were comprised of a mix of red clover (*Trifolium pretense*), white clover (*Trifolium repens*), and endophyte-infected tall fescue (*Festuca arundinacea*). Pasture nutrient composition can be found in Figure 1. Weather data were collected from Water and Atmospheric Resources Monitoring Program (Illinois Climate Network & Illinois State Water Survey) and can be found in Figure 2. The pairs on PAST had access to free-choice mineral (12 to 14% Ca, 5% P, 18 to 20% Na, 6% Mg, 375 mg/kg I, 400,000 IU/kg of vitamin A, 40,000 IU/kg of vitamin D_3, 400 IU/kg of vitamin E). Calves on PAST were fed creep [Pike 14% Beef Creep Pellet #C029; 85.3 % dry matter (**DM**) 86.0% organic matter (**OM**), 34.0% neutral detergent fiber (**NDF**), 19.2% acid detergent fiber (**ADF**), 2.6% fat, 14.4% crude protein (**CP**)] ad libitum three-weeks prior to weaning.

Prior to the initiation of the experiment, cows were synchronized with a 7 d CO-Synch + CIDR protocol as outlined by (Grussing et al., 2016), and artificially inseminated on d 0 (AI; 81 ± 15.3 d postpartum). Eleven days following AI, cows were exposed to bulls who had previously passed breeding soundness exams for a 51 d breeding season with 1 bull per group. Conception to AI and overall pregnancy were determined at 35 and 102 d post-AI, respectively. Conception to AI and overall pregnancy rates were determined by a trained technician via ultrasonography [Aloka 500 instrument (Wallingford, CT); 7.5 MHz general purpose transducer array].

All cows and calves received 1 mL/9.98 kg BW Eprinex (Merial, Duluth, GA) and were tagged with Python tags (2 per cow, 1 per calf) on d 34. Per OARC vaccination protocol, on d 62 calves received 5 mL Bovi-shield Gold FP5 VL5 HB (Zoetis, Parsippany, NJ), 2 mL Ultra Choice 8 (Zoetis, Parsippany, NJ), 2 mL MpB Guard (American Health Inc., Ronkonkoma, NY) and Covexin 8 (Merck, Madison, NJ) was given to steers at time of castration. A second round of vaccinations was given on d 89; calves received 5 mL Bovi-shield Gold FP5 VL5 HB (Zoetis, Parsippany, NJ), 2 mL Ultra Choice 8 (Zoetis, Parsippany, NJ), 2 mL MpB Guard (American Health Inc., Ronkonkoma, NY), and 1 mL/nostril Inforce 3 (Zoetis, Parsippany, NJ). Calves were poured with 1mL/10 kg of Dectomax (Zoetis, Kalamazoo, MI) before shipping to the University of Illinois Beef Cattle and Sheep Field Research Laboratory in Urbana, IL.

At the time of weaning, PAST cows and calves were brought into the drylot for a 6-day fence-line wean. The creep gate on the drylot calf pen adjacent to the cow pens was closed so that drylot cows and calves stayed in their original pens. All cows and calves were sorted and separated with only nose-to nose access to one another through the fence. The PAST cows and calves were housed identical to the DL cows during the fence-line wean period. During this time, drylot calves were fed the same TMR that was fed pre-weaning (TMR 3 in Table. 1). Pasture calves had ad libitum access to hay (84.7% DM, 86.8% OM, 61.6% NDF, 53.0% ADF 1.4% Fat, 7.5% CP) and to the same 14% commercial creep offered pre-weaning.

After the six day fence-line wean, calves were weighed and shipped 272 km to the University of Illinois Beef Cattle and Sheep Field Research Laboratory in Urbana, IL. Upon arrival, calves were weighed and sorted by original dam pen and sex. Calves were assigned to 12 pens [7-11 calves per pen (4.88 m × 10.36 m)] in the same barn with treatments separated and on opposite ends of the barn. Calves from each treatment were separated by 6 empty pens to minimize influence from other treatment on behavior. The barn was constructed of a wood frame with a ribbed metal roof and with siding on the north, west, and east sides. The south side of the barn was covered with polyvinyl chloride–coated 1.27 × 1.27 cm wire mesh bird screen and equipped with retractable curtains for wind protection. Pens had 4.88 × 4.88 m level slotted floors and 4.88 × 4.88 m solid sloped floor covered by interlocking rubber matting. Calves were fed in 4.27 m concrete feed bunks. Day 116 to d 158 is referred to as the receiving period. Calves were offered ad libitum access to a receiving diet (Table 4).

In year 2, one cow from the DL treatment was removed from the study due to excessive BW loss, data is reported until her removal. In year 2, one calf from the PAST treatment died from chronic respiratory disease, data is reported until removal. During the pre-weaning phase, 2 calves from the PAST treatment were treated for respiratory disease in year 1. In year 2, 1 calf from the PAST and 2 calves from DL were treated for respiratory disease. One calf was also treated for lameness in year 2. During the receiving phase, 1 calf from PAST was treated for respiratory disease in year 1 and 1 DL calf was treated for rectal prolapse and 1 DL calf for lameness in year 2.

Sample collection and analytical procedures:

Cow BW were collected at the initiation of the trial (81 ± 15.3 d postpartum; d 0), mid-summer [150 ± 18.8 d postpartum (d 54 in year 1, d 83 in year 2)], and at weaning (192 ± 15.3 d postpartum; d 111). A 4% pencil shrink was applied to cow BW on d 0 to account for gut fill since cows had been fed a common diet before the initiation of the study. No pencil shrink was applied for the mid-summer weight as cows were on different diets. At weaning, a single, shrunk

BW was collected (16-20 hour feed restriction; access to water). Cow BCS was evaluated at the same time points as BW collections.

Pre-weaning calf BW were collected at the initiation of the trial (81 ± 15.3 d age; d 0), at the time of weigh-suckle-weigh (**WSW**; 135.9 ± 15.1 d of age; d 55), at weaning (191 ± 15.3 d of age; d 111), and at the end of the fence-line wean (198 ± 15.3 d of age; d 117). Calf average daily gain (**ADG**) was determined through the pre-weaning period.

Milk production was estimated using the weigh-suckle-weigh (**WSW**) technique [(135.9 ± 15.1 d postpartum; d 55 (Beal et al., 1990)]. Twenty-four-hour milk production was determined on all cows and milk samples were collected from a random sub-set of 36 cows per treatment (6 cows per pen). Milk composition samples were collected by the hand stripping method (Clements et al., 2017) and analyzed for percent fat, percent protein, percent lactose, total solids, and milk urea nitrogen **(MUN**; Dairy Lab Services, Dubuque, IA**)**.

Cow hair coat scores (**HCS**; 1 to 5, in which 1 = slick, short coat and 5 = unshed, full winter coat) were evaluated and recorded at initiation of the trial (81 ± 15.3 d postpartum; d 0) and weaning (192 ± 15.3 d postpartum; d 111). Calf dirty score (**DS**) were evaluated and recorded at the initiation of the trial (81 ± 15.3 d of age; d 0), weaning (192 ± 15.3 d of age; d 111), and at the end of the receiving phase (240 ± 15.3 d of age; d 158). Dirty score was scored on a 1 to 5 scale, in which 1 = no tag, clean hide and 5 = lumps of manure attached to the hide continuously on the underbelly and side of the animal from brisket to quarter; as described by Busby and Strohbehn, (2008).

Locomotion score was evaluated at the initiation of the trial, AI pregnancy-check (115.9 ± 15.3 days postpartum; d 34), and weaning on a 4-point scale to determine lameness (0 = normal; animal walks normally, with no apparent lameness or change in gait: 3 = severe lameness; animal applies little to or no weight to affected limb and is reluctant or unable to move; as described by the Zinpro Step-Up Locomotion Scoring System (Zinpro, 2014). During the trial, cows identified with foot lameness were treated for either foot rot or digital dermatitis. Per OARC farm protocol, cows treated for foot rot received 3 mL/45.36 kg of Noromycin LA-300 (Norbrook Inc, Lenexa, KS). Digital dermatitis was treated by wrapping the hoof with 10 ml/foot of Noromycin LA-300. Foot scores were collected on cows and calves those time-points and quantified using the American Angus Association's simple foot scoring system. The system characterizes cattle for two traits: foot angle and claw set. Both scores are ranked on a 1-9 system with 5 being ideal. Claw set (1 to 9, in which 1 = extremely weak, open divergent claw set and 9 = extreme scissor claw and/or screw claw) and foot angle (1 to 9, in which 1 = extremely straight pasterns and 9 = extremely shallow heel and long toe). Claw set and foot angle were evaluated on calves on d 0 and d 110. All foot scoring data was collected by 2 trained observers and scores were averaged.

Calf behavior was observed for 12 h on d 111 and d 112 during the fence-line wean. Cattle were fed at 0800 both days and behavior was observed from 0800 to 1900 on day 1 (due to weighing the cows at 0700) and from 0700 to 1800 on day 2. Behavior was observed every 20 minutes, and 3 observations were averaged to represent each hour. The number of calves lying, walking, eating, and drinking were recorded. Pens were sampled for vocalizations for 2 minutes per pen for each 20 minute interval. Any audible vocal sound that could be attributed to a specific pen being evaluated was counted as a vocalization. Total number of vocalizations during each of the three 2-minute periods were used to calculate number of vocalizations/calf per hour.

Upon arrival to the feedlot, calves were sorted by original dam group and sex. Body weight was recorded upon arrival on d 116 and on d 137, final BW for all calves was determined by averaging a 2-d consecutive BW on d 157 and 158. Calves were scored for DS, claw set and foot angle at the end of the receiving phase. Dry matter intake (**DMI)**, ADG, and gain:feed (**G:F**) were evaluated to determine calf performance. Behavior was observed on d 117 and d 118 of receiving phase for 12 h. Cattle were fed at 0700 and calf behavior was observed from 0700 to 1800 on both days. Behavior was observed using the same collection method that was used during the fence-line wean.

Sample Analysis

During the preweaning phase, ingredient samples were collected biweekly from DL and were composited for analyses. Forage samples from PAST treatment were hand-clipped biweekly and composited by month. Feed refusals were collected biweekly and at time of a diet transition for calves in the drylot. Creep refusals for calves on pasture treatment during the preweaning phase were collected weekly for each of the final three weeks prior to weaning. Feed refusals were collected at the end of the fence-line wean phase and weekly during the receiving phase. All feed refusals were weighed and a subsample was collected for DM determination.

Forage and ingredient samples were dried in a 55°C forced air oven for 3 d and then ground with a Wiley mill (1-mm screen, Arthur H. Thomas, Philadelphia, PA). Forage and ingredient samples were analyzed for dry matter (24 h at 105°C), neutral detergent fiber and acid detergent fiber (using Ankom Technology method 5 and 6, respectively; Ankom200 Fiber Analyzer, Ankom Technology, Macedon, NY), ether extract (using Ankom Technology method 2; Ankom XT10 Fat Analyzer, Ankom Technology), crude protein (Leco TruMac, LECO Corporation, St. Joseph, MI, and organic matter (600°C for 12 h; Thermolyte muffle oven Model F30420C, Thermo Scientific, Waltham, MA).

Statistical Analysis

Pen was used as the experimental unit for all variables. The MIXED procedure of SAS (Version 9.4, SAS Inst. Inc., Cary, NC) was utilized to analyze all variables excluding cow reproductive performance and percentage of cows treated for foot lameness. Random effects included year and pen nested in treatment for models with individual animal observational units. Fixed effects of treatment, previous treatment, and cow age were all included in the model statements for all variables for cows. For cow BW, BCS, HCS, foot angle, claw set, and locomotion score, individual animal was considered as the observational unit with day 0 values included as a fixed effect for each of the following time points for the respective parameters. Milk EPD was included as a fixed effect for analysis of milk production. Treatment, calf age, sex, sire and cow age were included as fixed effects in the models for all variables pertaining to calf performance. For calf BW, DS, foot angle, and claw set, individual animal was considered as the observational unit with day 0 values included as a fixed effect for each of the following time points for the respective parameters. Weaning weight EPD was included as a fixed effect for BW at d 55, d 110, and d 116. Yearling weight EPD was included as a fixed effect for BW through the receiving phase. During the fence-line wean and receiving phase, growth performance parameters were evaluated using pen averages as the observational unit with treatment and sex as fixed effects.

The GLIMMIX procedure of SAS (Version 9.4, SAS Inst. Inc., Cary, NC) was utilized to analyze cow reproductive performance (AI conception rate and overall pregnancy rate) and percentage of cows treated for foot lameness. For those parameters, previous treatment and treatment were included in the model as fixed effects and year and pen nested in treatment were included as random effects. The REPEATED statement was used to model the repeated measurements within pen for calf behavior and vocalizations and the compound symmetry covariance structure was used based on the lowest AIC value. Pen was the observational unit for behavior. Fixed effects included sex, treatment, time, and the interaction of treatment and for behavior. Year was included as a random effect. Least square means function of SAS was used to separate treatment means. The SLICE statement was used to separate least square means when the interaction of treatment and time was significant ($P \leq 0.05$). Significance was declared at $P \leq 0.05$ and trends discussed at $0.05 < P \leq 0.10$.

RESULTS

Cow performance

Cow BW and BCS data are reported in Table 5. There was no difference ($P = 0.65$) in cows on d 0, DL had greater BW ($P < 0.01$) at the time of mid-summer BW collection and greater BW ($P < 0.01$) at time of weaning compared with cows maintained on PAST. There were no differences ($P \geq 0.16$) detected in BCS between treatment groups at any time point

Milk production, milk composition, and reproductive performance.

Milk production and milk composition data are reported in Table 6. Cows on DL tended ($P = 0.09$) to have greater milk production compared with cows on PAST. There were no differences ($P \geq 0.18$) detected for percent fat, percent protein, percent lactose, or total solids between treatments. However, PAST cows had greater ($P < 0.01$) MUN compared to DL cows. Artificial insemination and overall pregnancy rates are reported in Figure 3. There were no differences ($P = 0.38$) for AI pregnancy rate between DL (60.7%) and PAST (54.4%). Similarly, there were no differences ($P = 0.28$) for overall pregnancy rate between DL (92.6%) and PAST (95.9%).

Hair coat score and dirty score

Hair coat score and dirty score data are reported in Table 7. There were no differences (P = 0.90) in cow HCS on d 0. Hair coat score was greater (P < 0.01) for cows on PAST at weaning compared to cows on DL. Calves in the DL treatment tended (P = 0.09) to be dirtier at the beginning of the trial compared to PAST calves. Calves in the DL treatment were dirtier (P = 0.03) compared with calves in the PAST treatment at weaning. However, at the end of the receiving phase, calves in the PAST treatment were dirtier (P = 0.04) compared to DL calves.

Locomotion, foot treatment, and foot scores

Locomotion scoring and foot treatment data are reported in Table 8. There were no differences ($P \geq 0.18$) in cow locomotion at the start of the trial (d 0) or at mid-summer time point. However, cows in the DL tended (P = 0.09) to have greater locomotion scores at weaning compared with cows on PAST. There were no differences (P = 0.13) in the percentage of DL (36.0%) and PAST (5.0%) cows treated at least once for foot rot or digital dermatitis. However, more (P = 0.04) DL (7.0%) cows were treated twice or more than PAST (1.0%) cows. Claw set and foot angle scores are found in Table 9. There were no differences ($P \geq 0.12$) in foot angle or claw set scores for cows between treatments at any time point. There were no differences ($P \geq$ 0.12) in foot angle or claw set scores for calves at the start of the study or at weaning although DL calves tended (P = 0.10) to have a greater claw score at the end of the receiving phase compared to PAST calves.

Calf performance through weaning

Calf performance data during the pre-weaning phase are reported in Table 10. There were no differences (P = 0.96) on d 0 for calf BW. Calves on DL had greater BW (P < 0.01) at time of WSW and at weaning compared to calves on PAST. Calves on DL continued to have greater BW

($P < 0.01$) through the end of the fence-line wean compared to PAST calves. Calves on DL had greater ($P < 0.01$) pre-weaning ADG compared to calves on PAST (1.4 vs 1.1 kg/d, respectively). The DMI for DL calves is reported in Table 1. In 2019, calves on DL had a DMI of 0.9 kg/d on TMR 1, 1.9 kg/d on TMR 2, and 3.1 kg/d on TMR 3. In 2020, calves on DL had a DMI of 0.9 kg/d on TMR 1, 2.7 kg/d on TMR 2, and 3.8 kg/d on TMR 3. The creep feed DMI for the final 3 weeks of the experiment for PAST calves is reported in Table 2. Calves on PAST had an average DMI of 0.8 kg/d during week 14, 2.5 kg/d during week 15, and 3.4 kg/d during week 16. Calf DMI during the fence-line wean is reported in Table 3. Calves on PAST tended ($P = 0.10$) to have greater DMI compared to calves in the DL.

Weaning behavior observations

Behavior observations of eating, lying, walking, drinking and vocalizations for d 111 are reported in Figure 4. On d 111, treatment × time effects were detected ($P < 0.01$) for eating and lying, and vocalizations. At h 0900 and 1000 more ($P \leq 0.05$) DL calves were eating. However, more ($P \leq 0.04$) PAST calves were eating at h 1800 and 1900. A greater proportion ($P \leq 0.04$) of PAST calves were lying at h 0900 and 1000. More ($P \leq 0.04$) DL calves were lying at h 1600 and 1800 and tended ($P \leq 0.08$) to be at h 1700 and 1900. The PAST calves vocalized more ($P = 0.02$) at h 0800 whereas DL calves vocalized more ($P < 0.01$) at h 1100 and tended ($P = 0.08$) to at h 1200. There was a treatment effect detected on d 111 ($P < 0.01$) for more PAST calves to be walking compared to DL calves. There were no treatment effects detected for eating ($P = 0.77$), lying ($P = 0.42$), or vocalizations ($P = 0.66$). There were no treatment or treatment × time effects detected ($P \geq 0.36$) in drinking behavior.

Behavior observations for d 112 are reported in Figure 5. There were treatment × time effects detected ($P < 0.01$) for eating, lying, walking and vocalizations on d 112. More DL ($P \leq$

0.04) calves were eating at h 0800, 0900, 1000, 1300 and 1500 than PAST calves. More (P < 0.01) PAST calves were lying at h 0900 and tended (P = 0.07) to be at h 1000. However, more (P < 0.01) DL calves were lying at h 1600. More ($P \leq 0.02$) PAST calves were walking at h 0700 and 0800. More ($P \leq 0.03$) PAST calves vocalized at h 0700 and 1600 and tended ($P = 0.07$) to be at h 1800. There were treatment effects detected ($P \leq 0.03$) for more PAST calves walking and vocalizing more. There was also a treatment effect detected (P < 0.01) for more DL calves eating on day 112. There was no treatment effect detected for lying (P = 0.23). There were no treatment or treatment × time effects ($P \geq 0.32$) detected in percent of calves drinking.

Feedlot arrival behavior observations

Behavior observations at feedlot arrival on d 117 are reported in Figure 6. Treatment × time effects were detected ($P = 0.03$) for lying on d 117. More (P < 0.01) PAST calves were lying at h 0800 and 1000 and tended (P = 0.06) to be at h 1700. There were also treatment effects ($P \leq 0.05$) detected for lying and eating where more PAST calves were lying and eating on d 117. There was a treatment effect ($P = 0.01$) detected where DL calves vocalized more compared to PAST. There were no treatment or treatment × time effects detected for walking ($P \geq 0.48$) or drinking ($P \geq 0.12$) on d 117.

Behavior observations at feedlot arrival on d 118 are reported in Figure 7. There were treatment × time effects ($P \leq 0.02$) detected for lying, walking, and drinking. More ($P \leq 0.05$) PAST calves were lying at h 0700, 0800, 1400, 1500, 1700, and 1800. Conversely, more DL calves were walking ($P \leq 0.05$) at h 0800, 1700, and 1800. More ($P \leq 0.05$) DL calves were drinking at h 0700, 0800, 1100, 1300, 1500, and 1800, and additionally tended ($P \leq 0.10$) to be at h 1400 and 1600. However, more PAST calves tended (P = 0.07) to be drinking at h 1000. There were also treatment effects ($P \leq 0.01$) detected for lying, drinking, and walking. More PAST calves were lying throughout the day whereas more DL calves were walking and drinking. There were no treatment or treatment × time effects detected for eating ($P \geq 0.69$) or vocalizations ($P \geq 0.18$) on 118.

Receiving phase calf performance

Receiving phase calf performance is reported in Table 11. The DL calves had greater BW ($P < 0.01$) upon arrival to the feedlot. The DL calves had greater ($P \leq 0.02$) BW at d 137 and end of receiving. Calves on PAST treatment had a greater ADG ($P = 0.03$) during the first 21 days compared to DL calves; however, there was no difference ($P = 0.30$) in ADG during final 21 days of receiving. Calves on PAST had a greater ($P < 0.01$) ADG throughout the entire 42-d receiving period. There were no differences ($P = 0.99$) in DMI in the first 21 days of the receiving phase. However, PAST calves tended ($P = 0.06$) to have a greater DMI (7.56 kg/d) compared with DL (7.23 kg/ d) during the final 21 days of receiving. Overall DMI during the 42-day receiving period was not different ($P = 0.37$). During the first 21 days of the receiving phase, PAST calves had greater ($P < 0.01$) G:F conversion than DL calves. DL calves however, had greater ($P = 0.02$) G:F compared to PAST calves during final 21 days of receiving phase. Regardless, PAST calves had greater ($P = 0.01$) G:F throughout the entire receiving phase.

DISCUSSION

The objective of this experiment was to determine the effects of housing cow-calf pairs in a drylot compared with pasture on cow performance and reproduction, in addition to calf performance and behavior at weaning and through the feedlot receiving phase. Cows housed in a DL maintained similar BW throughout the experiment and had greater BW mid-summer and at weaning compared to cows housed on PAST. Interestingly, there were no differences in BCS. However, both DL and PAST groups were in acceptable BCS at the end of the experiment (5.9

vs 5.7, respectively). By design, the DL cows maintained BW throughout the experiment as they were fed rations formulated to meet maintenance requirements (NASEM, 2016), unlike PAST cows whose diets are less predictable and weather dependent. In contrast, lactating cows in a drylot from May to December weighed 18 kg of BW less than those grazing native grassland (Anderson et al., 2013). The authors noted that this weight difference was driven by the quality of the fall pastures compared to the lower quality hay cows on drylot were provided. An evaluation of different wintering systems indicated cows grazing stockpiled perennial forages gained more BW compared with those grazing crop residue or consuming grass legume hay in a drylot (Hitz and Russell, 1998). However, similar to the current study, the authors reported that since cows in the drylot were fed at maintenance that would explain why BW did not change for the treatment. Cow-calf pairs maintained on pasture had improved BW compared to cows limit-fed in a drylot (Preedy et al., 2018). In that study, although cows on both treatments lost BW, cows on pasture had improved BW change (-33.7 kg) compared to drylot cows (-48.4 kg) from the beginning to the end of the grazing season. Waldron et al. (2006) found no differences in BW or BCS when cows were grazing stockpiled kochia-grass pastures compared to feeding harvested alfalfa hay in a drylot to maintain beef cows during the winter.

In the current study, cows on PAST lost BW. The authors believe that this is likely related to the pasture quality as reported in Figure 1 and weather data as reported in Figure 2. Through June and July, NDF and ADF increased which decreased forage digestibility (NASEM, 2016). As the plant matures in the later summer months, the digestibility decreased resulting in fewer nutrients available for the lactating cow. Additionally, crude protein decreased during those months. This decrease in pasture quality could partially be explained by the below-average rainfall in June. Pasture quality improvement in August is likely due to above-average rainfall in

July (2019) and August (2020). Differences in BW between PAST and DL cows could also be partially explained by the activity increment that is increased when cattle are grazing (NASEM, 2016). Ultimately, cow performance in drylots depends on the diet being fed while stocking rates, forage quality, and weather determine performance on pasture.

Cows on DL produced more milk than PAST cows (7.6 kg vs. 5.3 kg, respectively). Pasture quality may also explain this difference in milk production. There were no differences in milk composition besides an increase in MUN (4.8 vs 13.9 mg/dL, respectively). Moderate MUN in dairy cattle is described as 13.5 mg/dL and high MUN as 18 mg/dL (Guo et al., 2004). Cows on PAST in this study had a 13.9 mg/dL which is still considered moderate. Elevated MUN is typically the result of excess CP (DePeters and Ferguson, 1992) or negative energy balance (Huhtanen et al., 2015). Since cows in this study were grazing pastures of relatively low to moderate CP, the elevated MUN in PAST cows is more likely a result of being in a negative energy balance. As cows lose BW and are in a negative energy balance they have greater MUN concentrations (Huhtanen et al., 2015). The mobilization of body reserves increased blood levels of non-esterified fatty acids (NEFA) and ketone bodies to circulate in the body and raise MUN levels (Tammninga, 2006).

Although cows on pasture lost more BW than DL in the current study, there were no differences in reproductive performance between cows housed in drylots or pasture for AI pregnancy (60.7% vs 54.4%, respectively) or overall pregnancy rate (95.6 vs. 95.9%, respectively). It is important to note that both treatments were still in acceptable BCS throughout the experiment, both treatments had a BCS of 5.9 at the mid-summer collection. A BCS of 5 - 6 is recommended to ensure that cows are in adequate nutrition and have acceptable conception rates (Selk et al., 1988). Similarly, Anderson et al. (2013) observed no differences in overall conception rates for lactating cows housed in drylots or pasture when exposed to natural-service sires for a 45-d breeding season (84.2% vs 85.2%, respectively).

The dairy industry has identified hoof health and locomotion as a primary management consideration when housing cattle in confined facilities (Adams et al., 2017). In the current study, cow locomotion scores differed at weaning where DL cows had increased lameness. On this locomotion scoring system, a 0 is walking normally and 1 is walking with mild lameness where the animal does not exhibit a limp when walking. Therefore, even though the cows housed in a DL had an increased lameness score compared with PAST cows (1.4 vs 1.1, respectively), they still had a mild lame-score. Previous environment could have also influenced this difference as cows and calves in both treatment groups were housed in the drylot prior to the initiation of the study. Dairy cows housed in confinement with zero access to pasture had doubled the percentage of lame cows in comparison with cows given access to pasture (Haskell et al., 2006). Although culling for lameness in the beef industry is relatively low at 3% (USDA, 2008), lameness is one of the primary reasons for culling in confined dairy cows in the United States (Adams et al., 2017). Thus, the impact of drylot locomotion and lameness needs further investigation.

Large differences in cows treated for lameness could have a major economic impact on producers. The estimated cost of clinical lameness in dairy cattle approaches $500 per case (Whay and Shearer, 2017). The drylot pens were bedded as needed, however; as precipitation and humidity increases in the summer months, it is easier for the pens to have greater moisture which could have led to the greater incidence of bacterial infections.

Cows on PAST had greater HCS compared to cows on DL at weaning. Thus, cows on the DL treatment were able to shed better than PAST cows. Research has demonstrated that cows grazing infected tall fescue can lead to rough hair coats (Mayberry et al., 2017). Since PAST cows were grazing endophyte-infected tall fescue, this likely contributed to increased HCS. Calves in the DL had greater DS at weaning, yet; PAST calves had greater DS at the end of receiving. The drylot conditions could explain DL calves having a greater DS. Although pens were bedded as needed, the precipitation caused the pens to be damp. Considering PAST cows had greater HCS, the PAST calves may have also had greater HCS which would allow tag to attach to the hide easier during the receiving phase. Although a statistical difference was observed, it is still considered a clean score.

Similar to cows, calves housed in a DL had greater BW compared to calves raised on PAST. The DL calves had access to the cow TMR ration for a longer period compared to calves on PAST given access to creep for the final 3 weeks prior to weaning. Feeding creep in pasture settings three weeks prior to weaning is a common practice in the industry to prepare calves to consume feed before weaning (Rasby, 2007). These results are contrary to a study conducted by Burson (2017) who studied the effects of cows calving on pasture, confinement, or sandhills systems on the health and performance of calves through weaning. Calves on pasture treatment had greater BW and ADG compared to calves raised in confinement. In this study, however, calves in confinement were fed creep at a target of 1% of BW as-fed intake and, calves on pasture did not have access to creep. Confined calf access to creep started 30 days into the calving season and was fed through weaning. Preedy et al. (2018) conducted a study determining the effects of early or conventional weaning in drylot and pasture environments and reported that calves managed in confinement that were both early and conventionally weaned had greater BW than pasture calves weaned at either time point. Similar to the current study, drylot calves were supplemented with a TMR whereas pasture calves grazed native pastures. Similarly, pasture calves gained more weight when turned out on grass with their dam compared to drylot calves (Anderson et al., 2013). Both groups were given access to a 16% creep during the pre-weaning phase, drylot groups were weaned in late September whereas pasture calves were weaned in late October which could explain some of the differences in BW. In the current study, differences in cow milk production also likely contributed to differences in calf BW at the time of weaning as DL cows produced more milk than PAST cows.

The authors hypothesized that calves raised in a drylot would show less behavioral signs of stress at weaning since their environment had not changed and they were more adapted to the feed bunk. On d 111, more DL calves were eating in the earlier hours of the day whereas more PAST calves were eating creep or hay in the later hours of the day. This is likely due to the DL calves being more accustomed to the feed bunk and morning delivery of the TMR. More PAST calves were lying in the early hours on d 111 compared to DL calves. The authors speculate that this is because the calves on DL were eating at those hours. More PAST calves were walking on d 111 compared to DL calves. This is likely due to PAST calves entering a new environment and when cattle are adapting to a new environment they often walk the perimeter and were likely seeking their dam. These behavior results have commonalities to the findings of Price et al. (2003) where calves that were fence-line weaned on pasture spent more time eating than abruptly-weaned calves on pasture or in a drylot. Although Price et al. (2003) are comparing abrupt-wean to fence-line wean, this is similar to the current study since the PAST calves were in a new environment similar to that of an abrupt-wean. Yet, in the current study PAST calves are still in close proximity to the dam.

Additionally, on d 111, PAST calves vocalized more at h 0800 and DL calves vocalized more at h 1100 and tended to at h 1200. The authors speculate PAST calves were bawling for their dam early in the morning whereas DL calves were eating. Conversely, the DL calves were not vocal until the later part of the morning after they were done eating. The frequency of vocalizations emitted by the calf is perhaps the most important behavior indicative of stress (Enríquez et al., 2011). The high frequency of vocalizations may indicate the animal's state of frustration for being unable to receive its previous feed, care, or bond with the dam (Enríquez et al., 2011). Although calves in this study were both fence-line weaned, the PAST calves experienced a new environment which could explain the increase in vocalizations. Haley et al. (2005) reported that abrupt-weaned calves averaged 41.9 vocalizations which was approximately 30 times greater than calves weaned in two-stages. Similarly, Rauch et al. (2018) reported that calves weaned in two-steps also vocalized less 2 days post-weaning compared to abrupt-weaned calves.

On d 112, behavior observations were similar to the previous day. More DL calves were eating throughout the day compared to calves on PAST, especially in the morning hours. There were differences in lying behavior throughout the day where more PAST calves were lying in the morning hours. More PAST calves were walking in the morning and vocalized more before feed was delivered. Further work is warranted to understand the impacts of the housing system on behavior at weaning.

Interestingly, there was a difference in intake during the fence-line wean. The authors had hypothesized that calves on DL would eat more since they had remained in their original environment and were acclimated to the feed bunk, yet PAST calves tended to have greater DMI. This is surprising when considering more DL calves were eating during behavior observations on d 112. The authors hypothesize that this could be due to PAST calves compensating for their dams' decreased milk production by increasing forage intake prior to weaning. Additionally, calves on PAST had ad libitum access to creep and hay whereas DL calves only had access to the TMR. Differences in diet type and palatability could have contributed to differences in DMI.

Upon arrival to the feedlot, more PAST calves were lying at h 0800, 1000, and 1700. Additionally, more PAST calves were eating and PAST calves vocalized less than DL calves on d 117. Suprisingly, the DL calves showed more behavioral signs of stress upon feedlot arrival than the PAST calves as we had hypothesized that DL calves would be better adapted to a feedlot setting since it was similar to their pre-weaning environment. The authors speculate that this may be because this is the first time DL calves moved to a new environment, even though it was similar, they had been accustomed to being in close proximity with their dam. Whereas PAST calves had already had to adjust to a new environment. It is documented that the breaking of the bond between cow and calf is more indicative of the behavior of the calves than the loss of access to milk (Wiese et al., 2016). Stěhulová et al. (2017) reported that calves who weaned with greater ADG vocalized more than calves with poorer gains. In this study, DL calves weaned with greater ADG and also vocalized more than PAST calves upon feedlot arrival on d 117.

There were similar behavior observations on d 118 as on d 117. There were differences in the percentage of calves lying, drinking, and walking from either treatment at different parts of the day. More DL calves were drinking and walking whereas more PAST calves were lying. There were very few vocalizations from either treatment and no differences in eating. Rauch et al. (2018) and Price et al. (2003) also found commonalities in behaviors between days when observing calf behavior for two or more consecutive days.

Calves on the DL treatment had greater BW at weaning, thus, the authors were not surprised that they had greater BW throughout the receiving phase. It was surprising, however, that there were no differences in DMI during the first 21 days. The authors had hypothesized

DMI would be lower for calves raised on pasture as Fluharty and Loerch (1996) had found that newly arrived calves at the feedlot initially prefer diets that are similar in moisture and texture to feeds that they are familiar with. Calves on PAST had been adapted to a forage diet with pelleted creep supplement whereas DL calves were fed a TMR with similar ingredients. Interestingly, DMI was greater for PAST calves during the final 21 days of receiving but not different for the overall 42 d receiving period. The PAST calves had improved G:F and ADG during the first 21 days and the overall receiving period. The authors speculate that since the PAST calves were on a lower plane of nutrition preweaning, that they compensated when put on a higher energy diet during the receiving period. Similarly, Mathis et al. (2009) found that calves managed on pasture weaned lighter than calves weaned in a drylot but gained more BW during the first 75 d of finishing compared to drylot calves. However, Bailey et al. (2016) evaluated the effects of fence-line or drylot weaning on the performance of calves during weaning, receiving, and finishing. In this study, calves of 3 ranch origins were weaned for 28 days in either a drylot with complete dam separation and fed a diet formulated to promote ADG of 1 kg at a DMI of 2.5% of BW, or they were weaned on pasture with native forage and fence-line contact with their dam, or pasture with fence-line contact with their dam and supplemented the drylot diet in a bunk. Similar to the current study, Bailey et al. (2016) found that ADG was greater for drylot calves than either pasture groups during the weaning period. In contrast to the current study, however, DMI and G:F were greater for drylot calves than either pasture treatment during the 56-day receiving phase. Conversely, Boyles et al (2007) compared calves that were weaned at trucking, weaned 30 d before trucking and confined in a drylot, or weaned 30 d before trucking and pastured with fence-line wean contact with their dam. Steers from the drylot treatment lost 0.6 kg/d in the first week in the feedlot receiving whereas steers who were weaned at trucking gained 0.5 kg/d and those that were pasture-weaned gained 0.4 kg/d. Although BW gain in the subsequent 3 weeks were similar among treatments, the differences in the first week upon arrival were enough to impact overall gain during the receiving period. Calves weaned on pasture or on the truck had increased gains compared to calves weaned in the drylot at the end of the receiving period. Multiple management and nutritional factors contribute to differences in housing systems affect calf performance

In conclusion, with decreased land availability and natural resources in the Midwest, many producers are seeking alternative options for housing cow-calf pairs during the summer months. Housing cow-calf pairs in drylots resulted in increased BW and milk production compared to cows on pasture but did not affect BCS or reproduction. Housing cow-calf pairs in drylots did, however, result in increased lameness and number of cows treated for foot rot and digital dermatitis. Calves raised in a drylot had greater BW and ADG during the preweaning stage and maintained the BW advantage through the 42-day receiving phase. There were differences in behavioral stress for calves at weaning amongst both treatments. Drylot systems could be an alternative for producers that can utilize readily available feedstuffs. More research is needed to fully understand the long-term effects of housing cattle in these production systems.

TABLES AND FIGURES

Table 1. Drylot ration composition and proximate analysis on a dry matter basis.

	Year 1			Year 2		
Item	TMR 1	TMR 2	TMR 3	TMR 1	TMR 2	TMR 3
Ingredient, kg						
Corn silage	4.4	3.6	-	7.8	3.6	-
Ground hay	2.4	-	-	-	-	-
DDGS[1]	2.7	2.5	2.5	2.9	2.5	2.5
Corn stalks	2	2.3	3.4	2.7	2.3	3.4
Soybean hulls	-	-	2.4	-	-	2.4
Dry rolled corn	2.3	2	2.4	1	2	2.4
Supplement[2]	0.1	0.4	0.4	0.1	0.4	0.4
Total limit-fed amount kg/d:	14	10.9	11.1	14.5	12.9	11.1
Number of weeks fed[3]	2	6	8	2	12	2
Calf DMI[4] kg/d	0.9	1.9	3.1	0.9	2.7	3.8
Analyzed nutrient content, %						
Dry matter	68.1	68.2	83.4	62.1	69.3	87
Organic matter	88.7	88.4	87.6	89.5	89.1	88.9
Neutral detergent fiber	38.3	33.7	41.7	37.6	33.5	44.4
Acid detergent fiber	18.8	16.8	23	19.5	16.9	25.6
Ether extract	3.8	4.2	4	3.6	4	3.6
Crude protein	9.4	10.1	10.4	9.1	9.8	10.4

[1]Dried distillers grains with solubles

[2]Supplement contained 87.7% ground corn, 8.9% limestone, 1.8% trace mineral salt [8.5% Ca as calcium carbonate, 5% Mg as magnesium oxide and magnesium sulfate, 7.6% K as potassium chloride, 6.7% Cl as potassium chloride, 10% S as S8, prilled, 0.5% Cu as copper sulfate and Availa-4 (Zinpro Performance Minerals; Zinpro Corp, Eden Prairie, MN), 2% Fe as iron sulfate, 3% Mn as manganese sulfate and Availa-4, 3% Zn as zinc sulfate and Availa-4, 278 mg/kg Co as Availa-4, 250 mg/kg I as calcium iodate, 150 mg/kg Se as sodium selenite, 2,205 KIU/kg VitA as retinyl acetate, 662.5 KIU/kg VitD as cholecalciferol, 22,047.5 IU/kg VitE as DL-α-tocopheryl acetate, and less than 1% crude protein, fat, crude fiber, salt], 0.1% Rumensin 90 (198 g monensin/kg, Rumensin 90; Elanco Animal Health, Greenfield, IN), and 1.5% fat

[3]There were differences in the amount of weeks diets were fed due to ingredient availability

[4]calves were fed the same TMR as cows ad libitum in a pen adjacent to cows

Table 2. Pasture calf creep feed dry matter intake[1]

	DMI, kg/d
Week 14	0.8
Week 15	2.5
Week 16	3.4

[1]Pasture calves were fed a 14% Commercial creep (Pike 14% Beef Creep Pellet #C029, Pike Feeds; Pittsfield, IL) 3 weeks prior to weaning

Table 3. Calf intake during the fence-line wean[1]

	Treatment[2]			
	DL	PAST	SEM	P-value
DMI, kg/d	4.7	5.2	0.27	0.10

[1]All calves were fed in the drylot for 6 days during the fence-line wean
[2]Drylot (DL) calves fed TMR ad libitum and Pasture (PAST) calves were fed a 14% CP commercial creep and hay ad libitum

Table 4. Ingredient and nutrient composition of calf receiving diet on a dry matter basis.

Item	Receiving[1]
Ingredient, %	
Corn silage	32
Grass hay	20
Corn[2]	20
MWDGS[3]	18
Supplement[4]	10
Analyzed nutrient content, %	
Dry matter[5]	47.6
Organic matter	88.7
Neutral detergent fiber	31.1
Acid detergent fiber	15.9
Ether extract	4.2
Crude Protein	12.6

[1]Receiving diet was provided ad libitum from d 116 to 158

[2] High moisture corn was used in year 1, dry rolled corn was used in year 2

[3]Modified wet distillers grains

[4]Supplement contained 76.2% ground corn, 15.9% limestone, 6.0% urea, 0.91% trace mineral salt (trace mineral salt = 8.5% Ca as CaCO3, 5% Mg as MgO and MgSO4, 7.6% K as KCl2, 6.7% Cl as KCl2 10% S as S8 [prilled], 0.5% Cu as CuSO4 and Availa-4 [Zinpro Performance Minerals; Zinpro Corp, Eden Prairie, MN], 2% Fe as FeSO4, 3% Mn as MnSO4 and Availa-4, 3% Zn as ZnSO4 and Availa-4, 278 mg/kg Co as Availa-4, 250 mg/kg I as Ca(IO3)2, 150 Se mg/kg Na2SeO3, 2,205 KIU/kg vitamin A as retinyl acetate, 662.5 KIU/kg vitamin D as cholecalciferol, 22,047.5 IU/kg vitamin E as dl-α-tocopheryl acetate, and less than 1% CP, fat, crude fiber, and salt), 0.155% Rumensin 90 (198 g monensin/kg Rumensin 90; Elanco Animal Health, Greenfield, IN), 0.1% Tylosin 40 (88 g tylan/kg Tylosin 40; Elanco Animal Health), and 0.75% soybean oil

[5]The differences in corn made for slight differences in DM% between years: 44.3% in year 1, 50.9% in year 2.

Table 5. Influence of drylot housing or pasture on cow BW and BCS.

Item	DL	PAST	SEM	*P*-value
BW, kg				
Initial[2]	684	679	16.9	0.66
Mid-summer[3]	682	653	7.9	0.01
Weaning[4]	662	598	14.8	0.01
BCS				
Initial	6.7	6.6	0.11	0.59
Mid-summer	5.9	5.9	0.19	0.71
Weaning	5.9	5.7	0.15	0.16

[1] Drylot (DL) cow/calf pairs were housed on concrete lots with open front sheds, cows were limit-fed TMR formulated for maintenance and calves had ad libitum access to TMR; and Pasture (PAST) cows rotationally grazed pasture, calves offered creep feed 3 weeks prior to weaning

[2] 81 ± 15.3 d postpartum, a 4% pencil shrink was applied

[3] 150 ± 18.8 d postpartum; d 54 in year 1 and d 83 in year 2,

[4] 192 ± 15.3 d postpartum, 16-20 hour shrink with access to water was applied to account for differences in gut fill

Table 6. Influence of drylot housing or pasture on cow milk production and milk composition.

	Treatment[1]			
Item	DL	PAST	SEM	*P*-value
Milk production[2], kg/d	7.6	5.3	0.82	0.09
Milk composition[3]				
Fat, %	1.7	1.9	0.35	0.57
Protein, %	2.8	2.9	0.12	0.26
Lactose, %	4.9	4.8	0.09	0.18
Total Solids	10.6	10.7	0.34	0.61
MUN, mg/dL	4.8	13.9	1.00	0.01

[1] Drylot (DL) cow/calf pairs were housed on concrete lots with open front sheds, cows were limit-fed TMR formulated for maintenance and calves had ad libitum access to TMR; and Pasture (PAST) cows rotationally grazed pasture, calves offered creep feed 3 weeks prior to weaning

[2] Determined by weigh-suckle-weigh at 142 ± 11.5 d postpartum

[3] Determined from 36 cows per treatment (6 cows per pen)

Table 7. Influence of drylot housing or pasture on hair coat score and dirty score.

Item	Treatment[1]		SEM	*P*-value
	DL	PAST		
Cow HCS[2],				
Initial[3]	3.8	3.8	0.21	0.90
Weaning[4]	1.0	1.2	0.04	0.01
Calf dirty score[5]				
Initial[6]	1.2	1.1	0.04	0.09
Weaning[7]	1.7	1.3	0.11	0.03
End of Receiving[8]	2.2	2.8	0.23	0.04

[1] Drylot (DL) cow/calf pairs were housed on concrete lots with open front sheds, cows were limit-fed TMR formulated for maintenance and calves had ad libitum access to TMR; and Pasture (PAST) cows rotationally grazed pasture, calves offered creep feed 3 weeks prior to weaning

[2] Hair coat scores (HCS; 1 to 5, in which 1 = slick and 5 = unshed)

[3] Evaluated at 81 ± 15.3 d postpartum

[4] Evaluated at 192 ± 15.3 d postpartum

[5] Determine by a 5-point scale 1= no tag, clean hide and 5= lumps of manure attached to the hide continuously on the underbelly and side of the animal from brisket to quarter; as described by Busby and Strohbehn, (2008)

[6] Evaluated at 81 ± 15.3 d of age

[7] Evaluated at 192 ± 15.3 d of age

[8] Evaluated at 239.9 ± 15.3 d of age at the completion of the receiving phase

Table 8. Influence of drylot housing or pasture on cow locomotion score and % of cows treated.

Item	Treatment[1] DL	PAST	SEM	*P*-value
Cow Locomotion[2],				
Initial[3]	0.3	0.4	0.14	0.26
Mid[4]	0.8	0.5	0.13	0.18
Weaning[5]	1.4	1.1	0.18	0.09
Cows Treated[6],%				
1 treatment	36.0	5.0	-	0.13
2 or more treatments	7.0	1.0	-	0.04

[1] Drylot (DL) cow/calf pairs were housed on concrete lots with open front sheds, cows were limit-fed TMR formulated for maintenance and calves had ad libitum access to TMR; and Pasture (PAST) cows rotationally grazed pasture, calves offered creep feed 3 weeks prior to weaning

[2] Locomotion Score (0=normal; animal walks normally, with no apparent lameness or change in gait: 3=severe lameness; animal applies little to or no weight to affected limb and is reluctant or unable to move; as described from the Zinpro Step-Up Locomotion Scoring System)

[3] Evaluated at 81 ± 15.3 d postpartum

[4] Evaluated at 115.9 ± 15.3 d postpartum

[5] Evaluated at 192 ± 15.3 d postpartum

[6] Percentage of cows treated for foot rot or digital dermatitis

Table 9. Influence of drylot housing or pasture on foot angle and claw set scores.

Item	Treatment[1] DL	PAST	SEM	*P*-value
Cow				
Foot angle[2]				
Initial[3]	5.5	5.7	0.15	0.12
Mid[4]	6.5	6.4	0.11	0.15
Weaning[5]	8.0	8.0	0.14	0.94
Claw set[8]				
Initial[3]	5.0	5.0	0.11	0.36
Mid[4]	6.0	5.9	0.10	0.12
Weaning[5]	6.8	6.6	0.16	0.29
Calf:				
Foot angle[2]				
Initial[6]	4.5	4.4	0.09	0.18
Weaning[7]	5.1	5.2	0.21	0.12
End of Receiving[9]	5.1	5.0	0.50	0.12
Claw[8]				
Initial[6]	4.6	4.6	0.13	0.70
Weaning[7]	4.9	4.8	0.08	0.32
End of Receiving[9]	5.2	5.1	0.08	0.10

[1] Drylot (DL) cow/calf pairs were housed on concrete lots with open front sheds, cows were limit-fed TMR formulated for maintenance and calves had ad libitum access to TMR; and Pasture (PAST) cows rotationally grazed pasture, calves offered creep feed 3 weeks prior to weaning

[2] Angle scores (1 to 9, in which 1= extremely straight pasterns and 9= extremely shallow heel and long toe, as described by the American Angus Association)

[3] Evaluated at 81 ± 15.3 d postpartum

[4] Evaluated at 115.9 ± 15.3 d postpartum

[5] Evaluated at 192 ± 15.3 d postpartum

[6] Evaluated at 81 ± 15.3 d of age

[7] Evaluated at 192 ± 15.3 d of age

[8] Claw scores (1 to 9, 1 to 9, in which 1= extremely weak, open divergent claw set and 9= extreme scissor claw and/or screw claw, as described by the American Angus Association)

[9] Evaluated at 239.9 ± 15.3 d of age at the completion of the receiving phase

Table 10. Influence of drylot housing or pasture on calf body weight (BW) and average daily gain (ADG) during the pre-weaning phase.

Item	Treatment[1]		SEM	P-value
	DL	PAST		
BW, kg				
Initial[2]	135.1	135.2	6.57	0.96
WSW[3]	194.3	179.3	2.09	0.01
Weaning[4]	290.3	260.6	4.24	0.01
End of fence-line[5]	290.4	253.0	12.26	0.01
ADG, kg/d				
Pre-weaning ADG[6]	1.39	1.11	0.06	0.01

[1] Drylot (DL) cow/calf pairs were housed on concrete lots with open front sheds, cows were limit-fed TMR formulated for maintenance and calves had ad libitum access to TMR; and Pasture (PAST) cows rotationally grazed pasture, calves offered creep feed 3 weeks prior to weaning

[2] 81 ± 15.3 d of age

[3] Weigh-suckle-weigh conducted at 135 ± 15.1 d of age

[4] 192 ± 15.3 d of age

[5] 198 ± 15.3 d of age

[6] ADG calculated from d 0-d 110

Table 11. Influence of drylot housing or pasture on calf body weight (BW), average daily gain (ADG), dry matter intake (DMI) and gain:feed (G:F) during the receiving phase.

	Treatment[1]			
Item	DL	PAST	SEM	*P*-value
BW, kg				
d 116	282.4	247.3	12.8	<0.01
d 137	310.5	294.8	16.4	0.02
d 158	368.5	344.7	13.6	<0.01
ADG, kg/d				
d 116-137	1.74	2.65	0.15	<0.01
d 137-158	2.02	1.57	0.14	0.30
d 116-158	1.88	2.11	0.03	<0.01
DMI, kg/d				
d 116-137	6.72	6.73	0.84	0.99
d 137-158	7.23	7.56	0.21	0.06
d 116-158	7.12	7.28	0.40	0.37
G:F				
d 116-137	0.26	0.41	0.05	<0.01
d 137-158	0.28	0.21	0.02	0.02
d 116-158	0.26	0.29	0.02	<0.01

[1] Drylot (DL) cow/calf pairs were housed on concrete lots with open front sheds, cows were limit-fed TMR formulated for maintenance and calves had ad libitum access to TMR; and Pasture (PAST) cows rotationally grazed pasture, calves offered creep feed 3 weeks prior to weaning

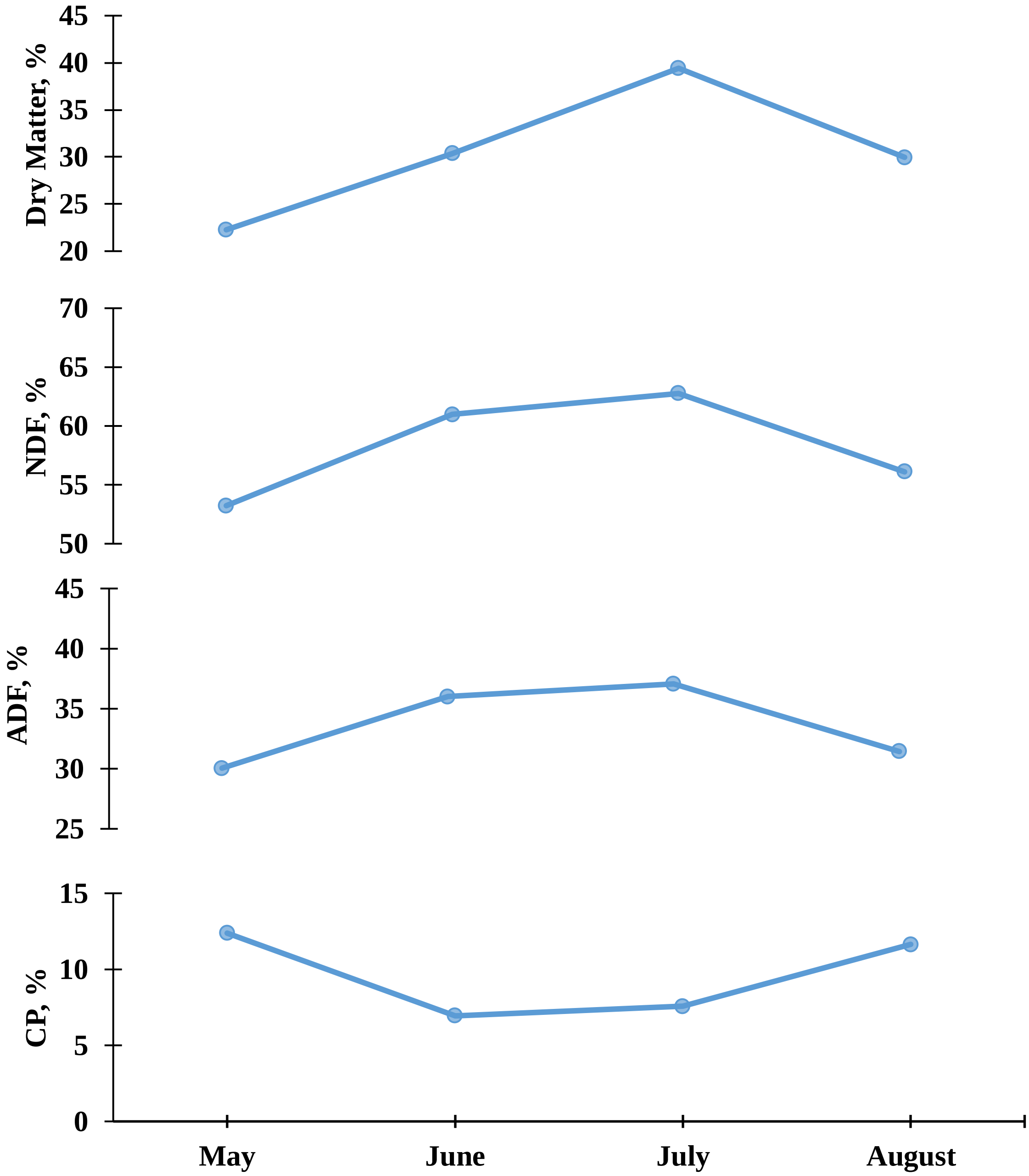

Figure 1. Forage quality [percentage neutral detergent fiber (NDF), acid detergent fiber (ADF), and crude protein (CP)] of endophyte-infected fescue (*Festuca arundinacea*), white clover (*Tri-folium repens*), and red clover (*Tri-folium pretense*) pastures from May to August.

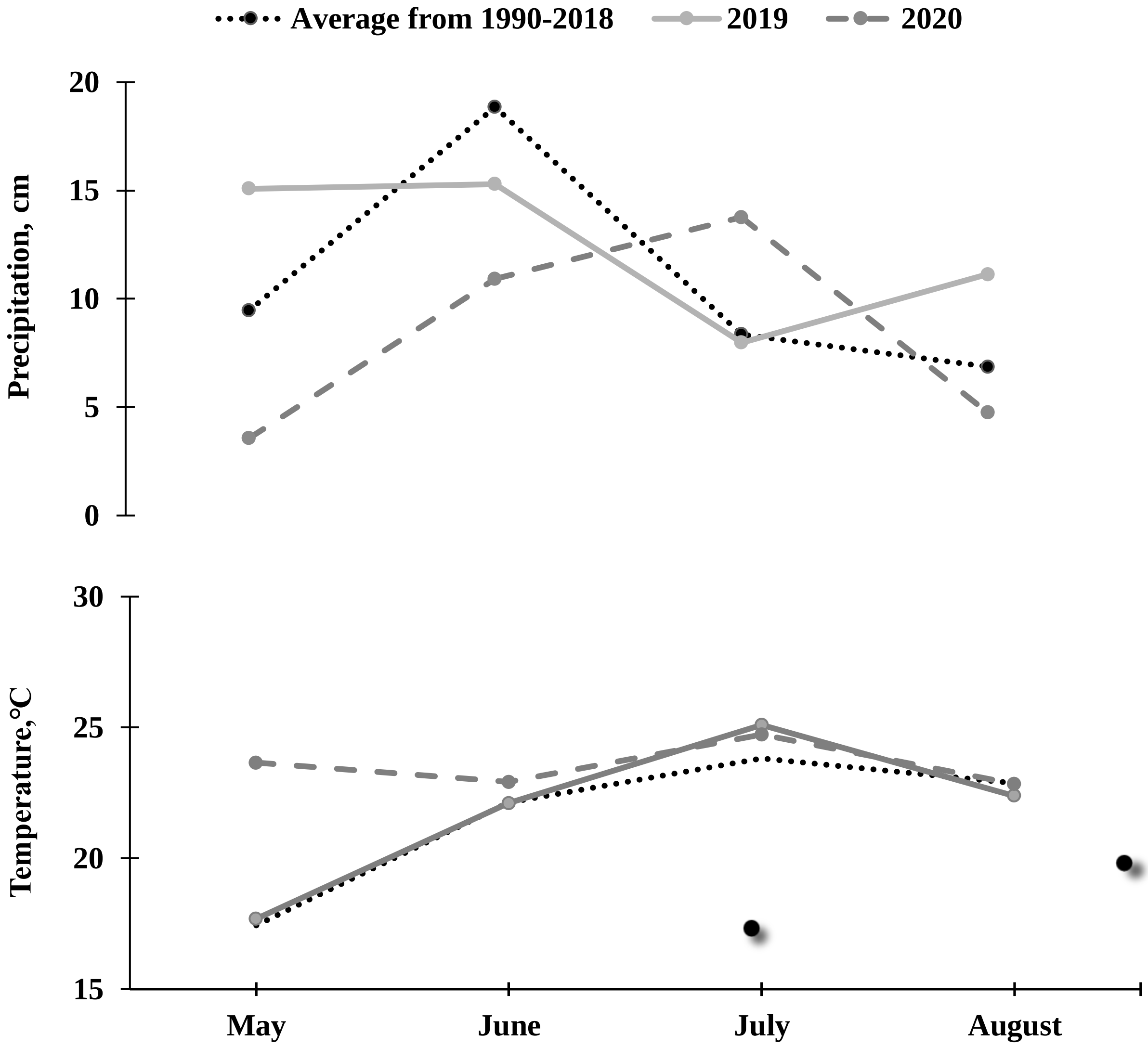

Figure 2. Comparison of precipitation (cm) and temperature (C°) at Orr Agricultural Research and Demonstration Center (OARC) in Baylis, IL from May 2019 to August 2019 and May 2020 to August 2020.

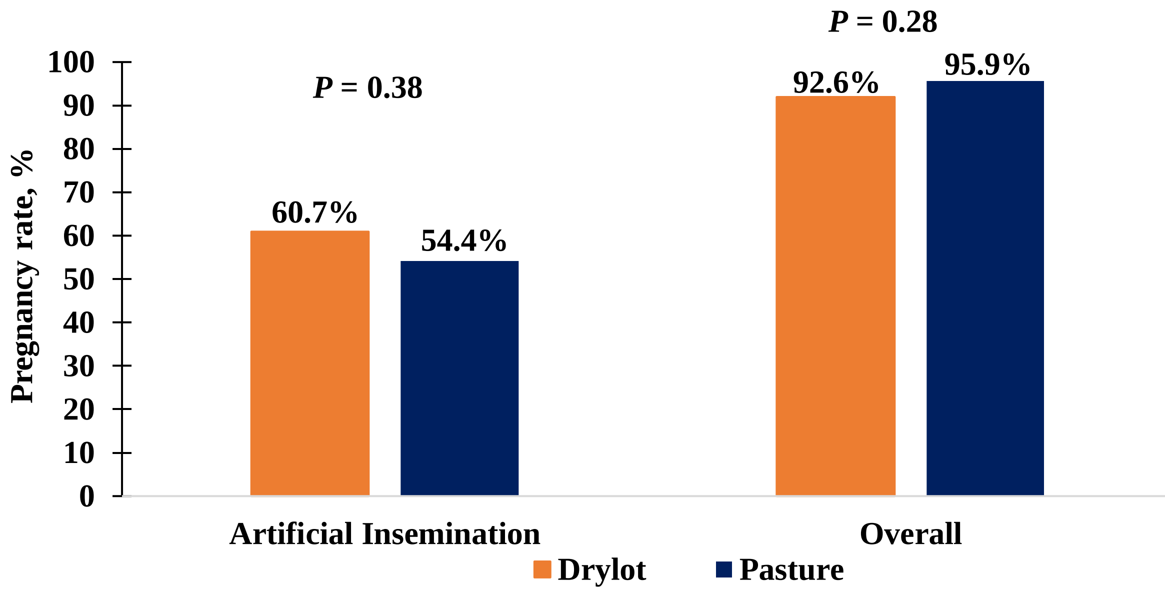

Figure 3. Influence of drylot housing or pasture on cow artificial insemination and overall pregnancy rate. Drylot (DL) cow/calf pairs were housed on concrete lots with open front sheds, cows were limit-fed TMR formulated for maintenance and calves had ad libitum access to TMR; and Pasture (PAST) cows rotationally grazed pasture, calves offered creep feed 3 weeks prior to weaning.

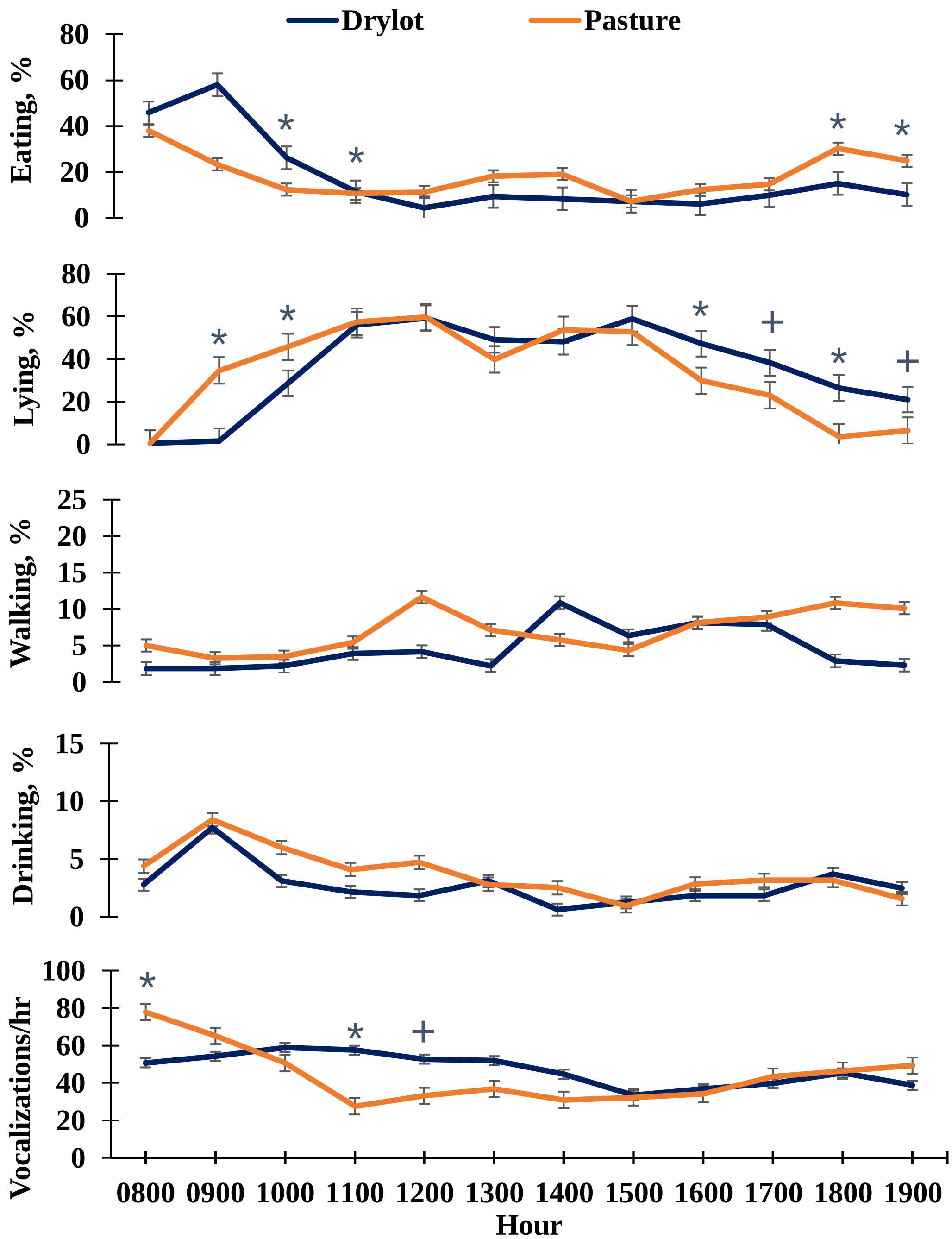

Figure 4. Influence of drylot housing or pasture on calf behavior at weaning on day 111. Drylot cow/calf pairs were housed on concrete lots with open front sheds, cows were limit-fed TMR formulated for maintenance and calves had ad libitum access to TMR; and Pasture cows rotationally grazed pasture, calves offered creep feed 3 weeks prior to weaning. Significance of hour slice P-values are represented as: $P \leq 0.05$ defined by *, and tendencies from $0.05 < P \leq 0.10$ are defined as +. Vertical bars represent the SEM. There were treatment × time effects ($P < 0.01$) detected for eating, lying, and vocalizations. There was a treatment effect detected for walking ($P < 0.01$) but no treatment effects ($P \geq 0.42$) for eating, lying, or vocalizations. There were no treatment or treatment × effects for drinking ($P \geq 0.36$). There was a time effect detected ($P \leq 0.01$) for each behavior.

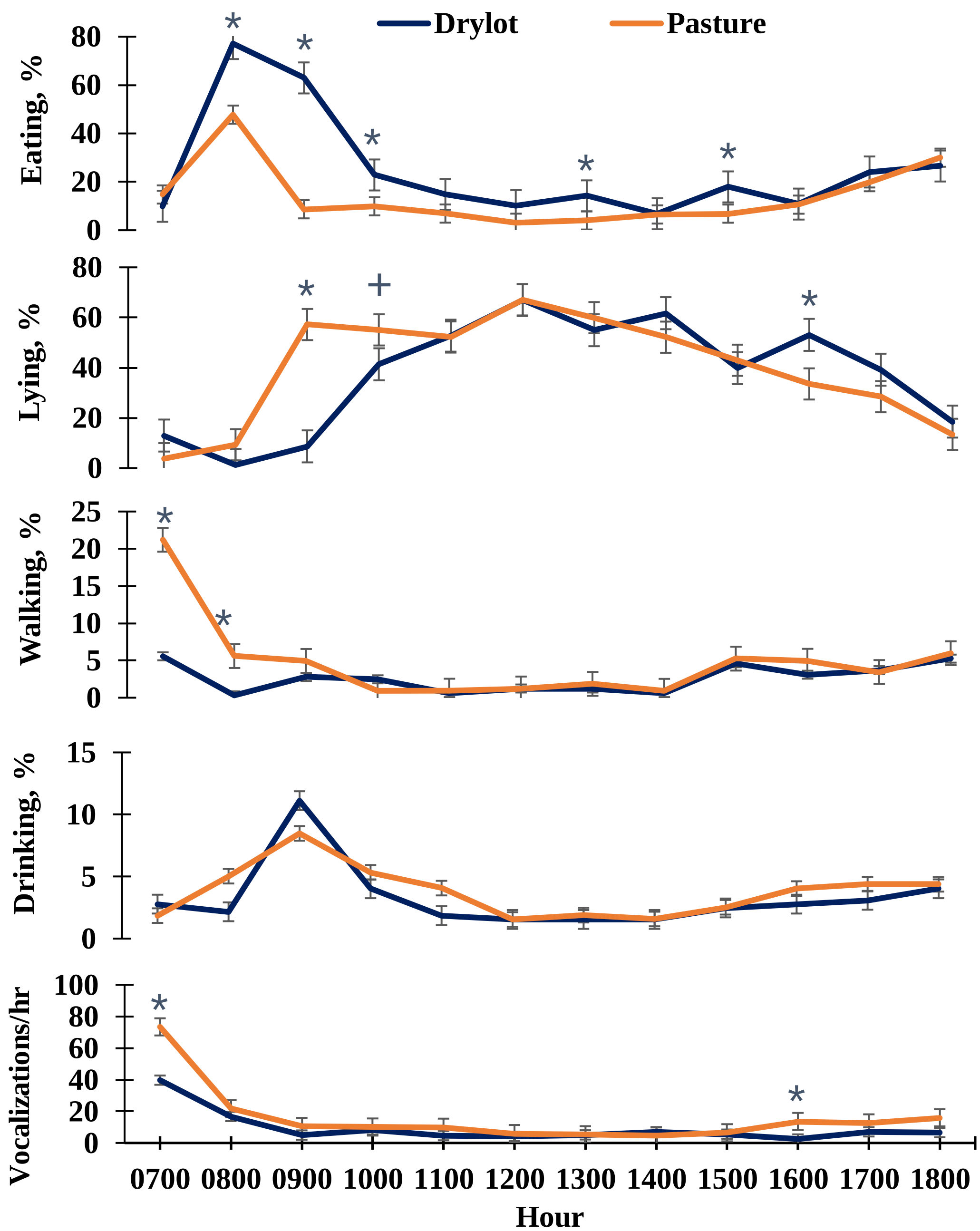

Figure 5. Influence of drylot housing or pasture on calf behavior at weaning on day 112. Drylot cow/calf pairs were housed on concrete lots with open front sheds, cows were limit-fed TMR formulated for maintenance and calves had ad libitum access to TMR; and Pasture cows rotationally grazed pasture, calves offered creep feed 3 weeks prior to weaning. Significance of hour slice *P*-values are represented as: $P \leq 0.05$ defined by *, and tendencies from $0.05 < P \leq 0.10$ are defined as +. Vertical bars represent the SEM. There were treatment × time effects detected ($P \leq 0.01$) for eating, lying, walking, and vocalizations. There were treatment effects detected ($P \leq 0.03$) for eating, walking, and vocalizations. There was no treatment effect detected for lying ($P \geq 0.23$). There were no treatment or treatment × time effects detected for drinking ($P \geq 0.32$). There was a time effect detected ($P \leq 0.01$) for each behavior.

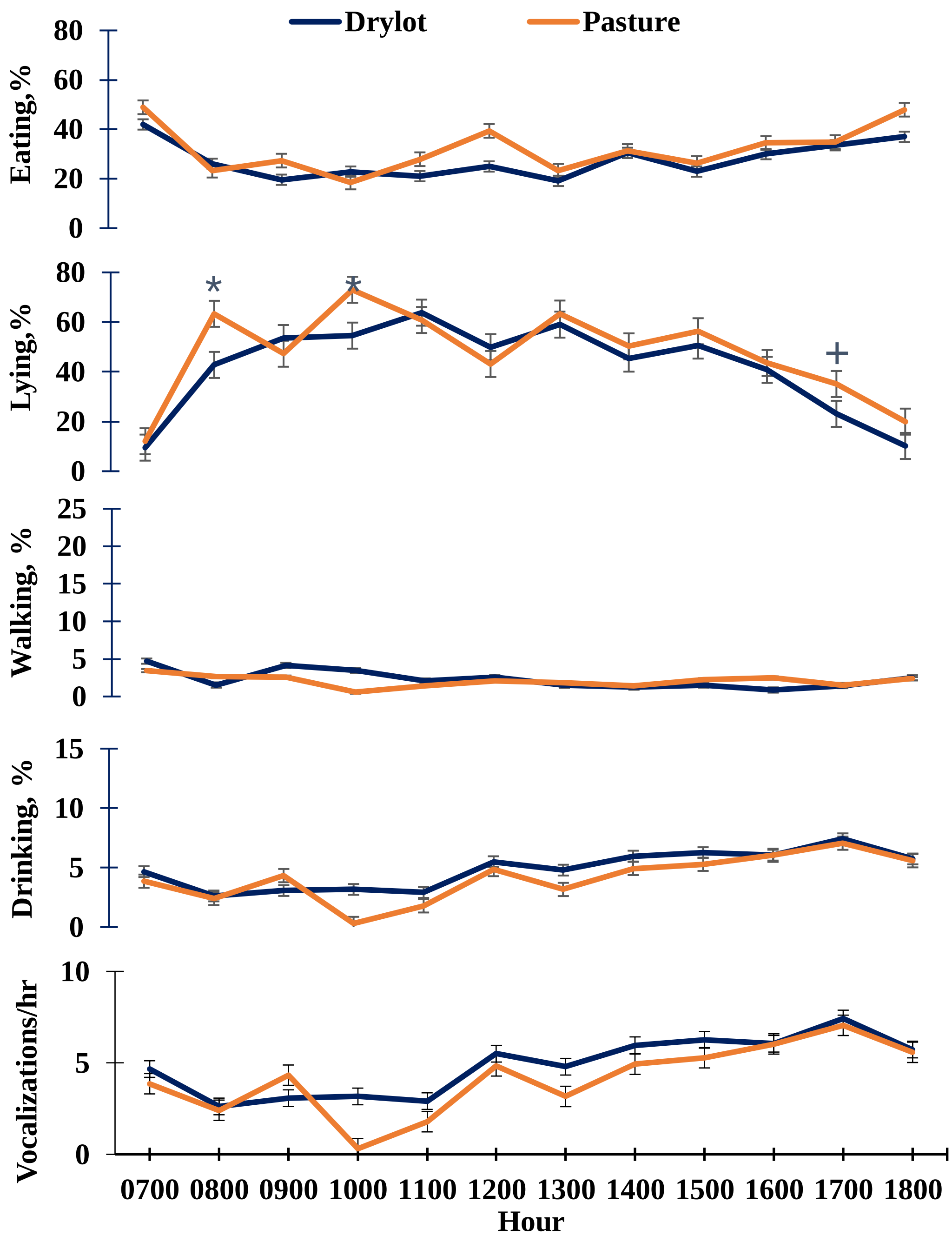

Figure 6. Influence of drylot housing or pasture on calf behavior at receiving on day 117. Drylot cow/calf pairs were housed on concrete lots with open front sheds, cows were limit-fed TMR formulated for maintenance and calves had ad libitum access to TMR; and Pasture cows rotationally grazed pasture, calves offered creep feed 3 weeks prior to weaning. Significance of hour slice *P*-values are represented as: $P \leq 0.05$ defined by *, and tendencies from $0.05 < P \leq 0.10$ are defined as +. Vertical bars represent the SEM. There was a treatment × time effect detected (P = 0.03) for lying. There were treatment effects detected ($P \leq 0.05$) for eating, lying and vocalizations. There were no treatment or treatment × time effects detected for walking ($P \geq 0.48$) or drinking ($P \geq 0.12$). There was a time effect detected ($P \leq 0.10$) for each behavior.

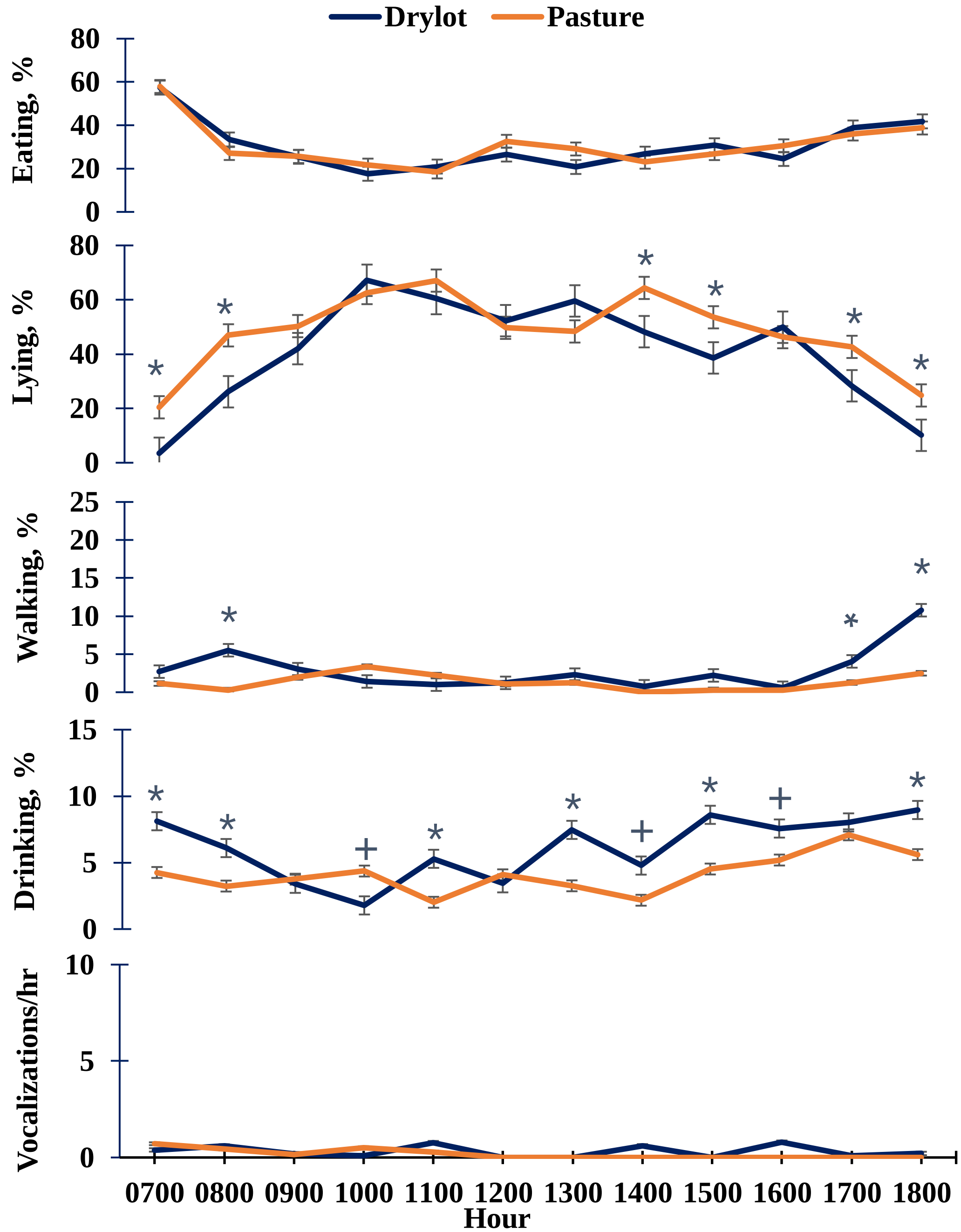

Figure 7. Influence of drylot housing or pasture on calf behavior at receiving on day 118. Drylot cow/calf pairs were housed on concrete lots with open front sheds, cows were limit-fed TMR formulated for maintenance and calves had ad libitum access to TMR; and Pasture cows rotationally grazed pasture, calves offered creep feed 3 weeks prior to weaning. Significance of hour slice *P*-values are represented as: $P \leq 0.05$ defined by *, and tendencies from $0.05 < P \leq 0.10$ are defined as +. Vertical bars represent the SEM. There were treatment × time and treatment effects detected ($P \leq 0.02$), for lying, walking and drinking. There were no treatment or treatment × time effects detected for eating ($P \geq 0.69$) or vocalizations ($P \geq 0.17$). There was a time effect detected for each behavior ($P \leq 0.01$) besides vocalizations ($P \geq 0.12$)

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