Effect of time of supplementation on performance and grazing behavior of backgrounded steers

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SCHOLARLY ABSTRACT

Beef cattle follow a daily, cyclical pattern of grazing, rumination, and digestion that coincides with their environment and season. Traditionally backgrounding operations hand feed any supplement in the morning. However, this practice may interrupt typical grazing patterns during early morning and subsequent rumination during the heat of the day. Self-fed concentrate feeds containing intake limiters are used to minimize the labor associated with hand feeding and allow cattle to eat throughout the day. The objectives of this experiment were to investigate the effect of supplement feeding time on performance and grazing behavior of backgrounded beef steers. Crossbred beef steers (n = 54; 7 ± 1 m of age; body weight, **BW** = 243 ± 2 kg) were sourced from a regional cattleman's association and grazed on tall fescue pasture (*Festuca arundinacea*) at the Southwest Virginia Agricultural Research and Extension Center in Glade Spring, VA from October 1 to November 8, 2019. Cattle were stratified by BW and source and allotted to 9 pasture groups (6 steers per pasture) in a randomized design. Pasture groups were randomly assigned to 1 of 3 treatments (3 pastures per treatment): 1) steers hand-fed supplement at 0930 h (**AM**), 2) steers hand-fed supplement at 1330 h (**PM**), or 3) steers fed a self-feeder supplement with an intake limiter (**SELF**). Hand-fed groups were fed a commercial commodity blend (39% corn gluten feed pellets, 30% cracked corn, 22% soy hull pellets, and 10% dried distillers grains) daily at 1.5% BW on an as fed basis. The SELF

supplement was a blend of 70% cracked corn and 30% of an intake limiter-containing pellet that was formulated to maintain voluntary supplement intake at 1.5% BW on an as fed basis. Cattle were weighed on 2 consecutive days at the start and end of the experiment, and feed adjustments were made following three interim weigh-ins. Motion-sensing cameras were used to monitor cattle visits to the feeder and waterer portions of the pasture. Treatment had no effect ($P \geq 0.13$) on calf BW, flesh condition score (**FCS**), dry matter intake (**DMI**), average daily gain (**ADG**), and backfat thickness. SELF steers were significantly ($P = 0.03$) more feed efficient than the AM supplemented groups and tended to have a greater ($P = 0.08$) G:F ratio for the PM supplemented groups vs. AM supplemented steers. Steers with access to a self-feeder showed behavioral differences to hand supplemented cattle, with more feeder visits in a 24 h period ($P = 0.01$) compared to AM and PM steers. Despite these behavioral observations, any disruption in natural grazing behavior was not dramatic enough to negatively influence backgrounded cattle growth performance; yet, cost of gain can be dramatically different between backgrounding diets.

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GENERAL AUDIENCE ABSTRACT

Grazing beef cattle tend to follow a general pattern of grazing, rumination, and digestion that coincides with their environment and the time of year. Backgrounded cattle managed in pasture-based systems are traditionally offered supplemental feedings in the morning. However, this practice could be decreasing how efficiently cattle utilize forage resources. Natural grazing behaviors are more intense preceding the heat of the day and interruption of morning grazing bouts could decrease forage intake by causing cattle to come to the feeder to consume supplement feedings. To examine how feeding time potentially influences performance and grazing behavior of backgrounded beef cattle, 52 crossbred beef steers 7 to 8 months of age and weighing 243 kg were grazed on tall fescue pastures at the Southwest Virginia Agricultural Research and Extension Center from October 1 to November 8, 2019. Cattle were supplemented with either a commodity blend or cracked corn mixed with an intake limiter. Cattle were sourced from 4 local producers and allotted to 9 pastures by body weight (**BW**) and source. Pasture groups were randomly assigned to 1 of 3 treatments (3 pastures per treatment): 1) steers hand-fed supplement at 0930 h (**AM**), 2) steers hand-fed supplement at 1330 h (**PM**), or 3) steers fed a self-feeder supplement with an intake limiter (**SELF**). Hand-fed groups were fed a commercial commodity blend (39% corn gluten feed pellets, 30% cracked corn, 22% soy hull pellets, and 10% dried distillers grains) daily at 1.5% BW on an as fed basis. The SELF supplement was a blend of 70% cracked corn and 30% of an intake limiter-containing pellet that was formulated to maintain voluntary supplement intake at 1.5% BW on an as fed basis. Adjustments were made to

the average BW of pasture groups, following three interim weigh dates at d 11, d 21, and d 30, to keep intake levels accurately at 1.5% BW. Flesh condition scores (**FCS**) were assigned, on a scale of 1 to 9, with 1 considered emaciated and 9 excessively fat. Ultrasound 12th rib fat thickness (**FT**) was measured on the first and final day of the experiment. Motion-sensing cameras were installed in each pasture to capture pictures every one-minute following motion detection. Subsequent pictures were used to analysis the number of feed and water visits, along with time of day, in an attempt to characterize intake behavior. There were no significant differences observed between treatment groups for BW, flesh condition score, DMI, ADG, and backfat thickness. Cattle on the SELF treatment had greater G:F than AM, with PM cattle being intermediate and not different than either. Steers with access to a self-feeder visited the feeder more than double the number of times in a 24 h period than either of the hand supplemented group. Despite differences in observed cattle behavior, any disruption in natural grazing behavior did not negatively influence performance of backgrounded steers, although cost of gain can vary significantly depending on backgrounding diet type.

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Review of Literature

Introduction

Beef cattle have traditionally been sold on a live weight basis; and thus, increasing the weight of marketed cattle receives a great deal of attention by beef cattle producers. Previous research has been conducted to investigate how individual components of the beef production cycle can be improved in the southeastern United States. Livestock in the southeast typically graze on land not suitable for crop production. Relative to other regions within the U.S. mild temperatures allow for properly maintained forages to be grazed through the fall months of September to November, with stockpiling potentially allowing for grazing to continue through the early parts of February. This provides the opportunity to manage weaned calves through a forage-based backgrounding or stocker program to prepare calves for a more successful entrance to a finishing program.

The balance of economic inputs to outputs within an operation's system is regarded as one of the greatest challenges for producers, and the opportunity to enhance profits through increasing sale weight prior to marketing is an option and according to (Hoveland, 1986). With a goal of increasing average daily gain (ADG), not all strategies are profitable because of the increased input costs that can may incur. Proper grazing management with appropriate stocking rates to match pasture acreage to maintain a strong forage stand with ample nutritive value may reduce the need for more costly supplementation. He goes on to further explain how this would allow the cost of maintaining one cow to be dispersed over a more extensive portion of a calendar year, by selling her calf each year at a higher weight. Increasing saleable weight with minimal inputs helps increase profitability per calf weaned, giving added value to each female that raises a calf in the herd when compared to selling freshly weaned calves directly off the cow. (Hoveland, 1986).

Stocker Cattle Programs

Many management systems exist within the cow-calf sector of the beef industry in relation to defining a calving season, nutrition and supplementation, weaning age, and development of the feeder calves. Southeastern cattle producers have traditionally marketed freshly weaned, feeder, or calves through graded feeder calf sales to feedlots in the Midwest or Great Plains where cattle are finished to market weights. According to an article backed by the American Angus Association, opportunities exist for producers or landowners wanting to enter the beef cattle industry, who have available forage to retain or purchase groups of calves to move through a transitional stocker phase between weaning and finishing (Peel, 2016).

The terms backgrounding calves and stocker cattle are used interchangeably in many regions, referring to the conditioning period following weaning used to assimilate and prepare calves for a smooth transition to the feedlot or finishing system. Profitability may be realized through compensatory ADG, “bunk broke” cattle, and reduced labor for the feed yard in dealing with health issues by calves previously vaccinated. Although similar in their overall purpose, backgrounding needs access to a cattle handling facility as well as some grade of a feeding facility and typically is 45 to 60 days, whereas stocker programs can take on many forms or lengths of time. There is a reliance on feed products with at least intermediate energy levels to support desired levels of ADG during “bunk training” cattle or teaching the cattle to consume feed products being offered. To protect themselves from taking major financial gambles, many backgrounding entities are vertically integrated with either the cow-calf or feed yard to add the valuable pounds to the calves. This allows cow-calf producers to increase saleable weight with reduced inputs, and feed yards allow the calves to grow in frame size without rushing them onto heavy concentrate rations, allowing for larger cattle to sell later at market weight (McKinnon and Snodgrass, 2005).

Stocker operations rely predominantly on high quality forage stands to increase body weight with little to no supplemental feed. Producers have options when purchasing calves. Including buying private treaty directly off the cow, from buying stations where small producers can come together to put a cohesive load of calves together, or a sale barn. Along with feeder cattle purchases, another option is to introduce another phase of putting condition on, by investing in previously backgrounded cattle. After initial processing, the minimal need for working facilities with a less intensive cattle management style, make this system appealing to those needing a secondary income. There is substantial risk involved with how reliant this system is to proper forage management and cultivation (McKinnon and Snodgrass, 2005).

As the commercial feed yards continue to increase in size, owners are more hesitant to deal with the issues associated with recently weaned cattle as stated by (McKinnon and Snodgrass, 2005). Challenges with arrivals to the feedlot include, strict timelines to move cattle in and out, low tolerance for waiting on cattle to learn to eat from the bunk, becoming acquainted to new cattle, or poor compensatory gains upon arrival. Within this type of system, these issues largely are due to comingling, or introducing small groups of calves from various operations together. Bovine respiratory disease complex is the leading infectious disease affecting stocker producers. One of the most critical aspects maintain health when receiving new cattle is a proper vaccination program and prompt symptom detection (Thomson and White, 2006). Other goals of stocker operations are to teach calves to drink from automatic watering systems, consuming forages or concentrate feed products, and to allow cattle to recover from the stress of weaning, shipping, and engaging with other cattle. How long it takes to achieve these goals is dependent on how cattle were managed before entering the stocker program.

Overall production goals can be broken into three different profit strategies. The value of the gain per head, improving cattle quality, and speculating the market (Thomson and White, 2006). The value of gain is determined by sale revenue minus the input costs. Cattle allowed to graze with more time have a greater likelihood of reaching genetic frame size potential, and added frame allows for more end product later in production. Having the cattle for longer periods of time allows for one to pay attention to the future's markets with more flexibility to sell at desirable prices to maximize profits. The fundamental decisions surrounding these strategies is what determines whether a stocker program sees success in the way of positive economic returns (Thomson and White, 2006).

Once the business goal has been decided, finding cattle that fit into the management system is imperative. The length of time the operation wants to keep the cattle, the resources available to utilize, and the type of cattle either available or desired by the feed yard are some factors in consideration. North Dakota State University extension states large framed cattle that are weaned with extra condition can be directly sent to the feedlot and to be fed out. Medium framed calves do well in a stocker growing system to allow them to reach mature size without becoming overly fleshy. Small-framed calves or calves that come the lightest weight off the cows are best suited for a longer stocker program, or a combination of backgrounding in combination with a stocker program to allow them to catch-up and allow adequate frame growth prior to finishing (Lardy, 1998).

Supplementing Cattle in Forage-Based Systems

Forage availability and quality can vary depending on weather conditions, time of year, soil fertility, or grazing management before and after receiving stocker cattle. With the goal to add weight gain profitably, supplementing cattle on pasture can be a strategy to conserve forage to extend the grazing period, boost animal performance, or increase return on investment of the purchase of stocker cattle (Kunkle, 2000). In three separate experiments conducted by Horn et al, (1995), stocking densities were raised between 22% and 44% to 1.65 steers/ha. when cattle were supplemented daily. As previously stated, another goal of supplementing backgrounding cattle includes preparing them for entrance into the feed yard, through bunk breaking, acclimating them to human interaction, and introducing them to feedstuffs for perhaps the first time (Lardy, 1998). When considering the type of supplement or timing of a supplementation program, each operation must evaluate their overall goals and nutritional value of the forage being consumed to properly supplement to compliment forages.

North Dakota State University Extension suggests a goal of 1.5 to 2.5 pounds of gain per head per day for stocker cattle (Lardy, 1998). When first introducing stocker cattle to a forage system, depending on the quality and quantity of forages available, they should be allowed a grace period where the first several days they may lose weight before picking up ADG once transitioned to their new surroundings. With many stocker programs in the southeastern U.S. occurring during the fall months, proper alignment of supplemental nutrition with the decline of forage quality is pivotal to support desired ADG without a lapse period as the forage growing season draws to a close.

Feeding locally sourced, inexpensive by-products, or those produced on the farm can keep input costs low and decrease cost of gain. Forage-based cattle however present a unique challenge in that variation of preferences, behaviors, and nutrient intake exists between each animal within similar pastures. When cattle have the option to select from a variety of forages at various stages of growth, it is hard to accurately know exactly what each animal is consuming. When estimating intake of forage, nutritionists must take into consideration gut fill and its rate of passage through the rumen as a cap on daily nutrient intake potential (Campling, 1970). This variation in nutrient intake remains true when feeding a supplement as it is unlikely that each animal is consuming an equal quantity of supplement and total dry matter intake. An approach for assessing pasture-based nutrition programs that was recommended by Kunkle (2000), is to consult the Nutrient Requirements of Beef Cattle and "provide sufficient protein, minerals and vitamins to balance deficiencies in the forage only if it will have a greater return over cost."

Region and feedstuff availability are the greatest limiting factors when developing or sourcing a supplementation ingredient or ration. Research conducted by Rittenhouse et al.; (1970) showed an inverse relationship between overall forage intake and amount of supplement consumed by the animal. Over their three-year study, an average of 57 grams of forage per kg of body weight was consumed per animal, when ample forage was available. If less than this amount is available per head, adding supplementation to fulfill deficit nutrients or forage mass may be necessary. The most common feedstuffs fed to cattle by producers and studied by researchers are those high in fiber, starch or crude protein. Commonly researched feedstuffs include corn or corn by-products, soybean hulls, cottonseed hulls, wheat products, or a combination of these ingredients. Inclusion rates should be based on mean body weight of calves within a group and should stay below a rate of 1.5% of body weight to allow growth without pushing the calves to become overly fleshy (Horn et. al., 1995).

Delivery method of these supplements has shown to be just as influential on ADG as the product being fed. Hand-feeding commodity blends in feeders or with a commodity mixing wagon are the most common delivery methods. The possibility of feeding range cubes or a cake mixture, which are feed products highly compressed into blocks, as a less labor-intensive route of supplement (Kunkle, 2000). Altering days of supplementation, instead of daily, is a way to further reduce time and labor spent supplementing cattle.

Previous research is conflicted regarding the ideal frequency of feeding to see consistent nutrient absorption. In several studies reviewed by Kunkle et al., (2000) grain-based supplements were fed either daily, every three days, or once per week. Notable improvements in body condition were observed among all treatments compared to non-supplemented control groups although little difference in ADG or organic matter intake were observed as a result of number of feedings per week. Although significance in nutrient intake improvements may not be detected, Lardy (1998) suggests feeding cattle at a consistent time, no matter the feeding frequency, is needed to acclimate cattle for the feedlot schedules of their next phase of life.

Feed Intake Limiters

Feed and labor costs and are factors that livestock managers must address when securing economic success of beef cattle operations. These issues have led to increased interest in utilizing self-feeding systems which allow cattle to consume supplement *ad libitum*. Yet it is not realistic to assume that supplement intake will be uniform across all cattle. Individual preferences or competition will compromise uniform intake even among a contemporary group. To better maintain feed intake at a target level of intake, certain feed ingredients can be added to a ration or supplement to limit feeding frequency and overall feed intake to a consistent, predetermined level.

The most common intake limiter used across beef cattle production is sodium chloride, or white salt, because of its availability and being considered a safe feed additive (Kunkle et al., 2000). The amount of salt incorporated into rations can range from 9% in an experiment conducted by Meyer et. al, (1955) to upwards of 35% in experiments conducted by Harvey et. al. (1986). Both experiments were effective at using salt to keep daily dry matter intake at desirable rates of intake, between 1.0% and 2.0%. Pelleting decreases the effectiveness of salt as a limiter in rations. When the salt is encapsulated within the pellet with other feedstuffs, more time is needed for the rumen to break down the pellet before the salt limits the intake levels (Harvey et. al, 1986).

Brandyberry et. al. (1991) observed that steers fed a salt-limited supplement visited the feeder around 1200 PM, when there was a lull in their grazing behaviors. Even with continuous access to self-feeders, this study reported cattle averaged only 1-2 feeder visits per day for the duration of the trial. The drawbacks noted by using salt as a limiter is an increase in water consumption by up to 35% daily as reported by Meyer et. al (1955). The research also found the excess salt caused a significant increase in the weight of the kidneys in the steers on the ration. It is recommended to start adding salt at a level of 0.1% of body weight, monitor intake, adjust as needed, and acknowledge that as cattle become acquainted to salt levels, their tolerance will increase (Kunkle et. al, 2000).

An additional option of adding monensin to a salt-limiting supplement has been shown to reduce the amount of salt needed to limit intake in cattle. Muller et. al (1986) reduced the level of salt within the ration between 25 and 50%, helping to alleviate the adverse effects of increased water consumption and enlarged kidneys seen with excessive sodium chloride levels. A self-fed supplement containing 4.4% salt and added monensin fed to stocker cattle grazing wheat pasture, reduced intake levels from 2.28 to 0.65 kg/d, and additionally limited the variation of daily intake (Paisley and Horn, 1997).

Fats and oils used as a limiter not only can offer added energy boosting average daily gains, but this energy is utilized when a low-quality forage is being grazed or provided. Wise et. al (1965) added 10% fat to ground corn successfully limiting supplement intake to 1.0% of body weight in steers being finished in a forage-based system. These cattle relative to the control saw a 7% increase in weight gained. Hydrolyzed animal fat, vegetable oil, or a combination of the two have been used successfully. Compared to minerals, these products tend to be expensive and are better employed to hold cattle's grain intake to 1 to 2% body weight rather than attempting to hold protein or energy supplements to 1 kg/d (Kunkle et. al., 2000). Excessive fat within the diet can have negative effects on digestion and rumen fermentation. Rumen protozoa and the overall efficiency of the rumen can be drastically reduced as fat levels increase (Onetti et al., 2001). Depending on location, the composition of fats and oils can prove to be challenging to store or handle in extreme climates either hot or cold.

Commercial feed limiting products have been developed in an effort to address the shortcomings of single ingredient limiters previously discussed. Many of these products contain proprietary, non-salt intake limiters that promote smaller, more frequent meals throughout the day. The goal is to keep forage intake high, utilize added supplement to boost overall nutrient intake levels, thereby increasing cattle performance. A nutritionist should be consulted when formulating the ration, to set the optimum intake level per head, per day, to see maximum product utilization for an appropriate cost.

Other limiter products and compounds exist but may not have as many implications, as well as have concerns from either a nutritional, handling, or economic standpoint, in terms of their implications across a large multitude of operations. Commercially available products can be easier to implement from a labor and ease of mixing standpoint. It is important to know the overall intake level desired to ensure cattle receive a balanced diet from both supplement and forage available. No matter the limiter product used, ensuring there are proper amounts of forage available, a clean water source available, and the supplement present for the cattle at all times cannot be overemphasized to see successful implications (Kunkle et. al., 2000).

Grazing Behavioral Studies

Producers managing grazing cattle would benefit from an understanding of grazing behavior to allow for supplement delivery during times that the animals are not naturally grazing. There are numerous factors that can shift grazing habits and even within a contemporary group, behaviors and requirements differ among individuals. In a study conducted in Virginia, it was noted that the largest factors influencing cattle behaviors was the overall forage quantity and palatability. Influential factors cited included management practices, climate, addition of supplementation, daylight seasonality, and production stage of the cattle (Sheppard et. al., 1957). Knowledge of the factors that impact grazing behavior can be used to tailor management decisions to support greater forage utilization, growth, and ultimately profits.

There is variation in the literature with respect to time spent grazing; however, most estimates suggest that cattle graze for 7 to 8 hours of each 24-hour period, or 30% of the day (Cory, 1927; Sheppard, 1927). The period in which cattle are actively grazing is not limited to daylight hours and they have been shown to have periods of grazing throughout the night (Giobel and Lindbom 1933). Hodgson (1933) observed a reduction of grazing time by 28 minutes in cattle that were rotationally grazed compared to a continuous grazing system, yet they saw a higher frequency of grazing behavior. This is consistent with Hein (1935) who saw a direct relationship between grazing time and amount of foliage available, increasing the time cattle were out searching for forage from 8 hours and 45 minutes to 10 hours per day when forage availability was limited.

A 1957 study implemented in Virginia studied grazing behaviors and intensities as 30 steers were rotated among different vegetative varieties in 6 pastures. This was to test the theory producers previously believed, that cattle would graze according to which pasture they found the most palatable and to discern if there was an inverse relationship between grazing intensity and increasing daily temperature. Results of the study produced an average grazing time of 6.7 to 7.9 hours, with no significance shown amongst the differing pasture types. Perhaps the most compelling data pulled from the study was not seeing any effect on time spent grazing in relation to heat of the day, contrary to expectations (Sheppard et. al., 1957).

Cumulatively the time of grazing can be grouped into two major events with a minor event in the middle. Much of the grazing took place between 4 and 8 AM. This is accredited to the livestock waking up and needing to begin filling up to ruminate as the temperature begins to warm up. During the middle of the day grazing is reduced comparatively, roughly 16 to 27% of cattle will be grazing during the hours of 10 AM and 4 PM (Sheppard et. al., 1957). From 4 to 8 PM the other major grazing events take place, as the cattle prepare to bed down for the night, and they need to refill for overnight rumination.

Though many times coined creatures of habit, several studies have reported variability in grazing behaviors. On consecutive days, behavior can vary greatly, to make up for any deficit or surplus nutrients (Rittenhouse, L. R., et al., 1970). The experiment also suggests on average cattle will consume 57 g per kg of body weight in forage per day. This number will fluctuate depending on if supplementation is offered, thereby decreasing the need for that much forage intake. When pasture quantity becomes limited, some cattle appeared to add in smaller grazing periods to make up for smaller meals consumed, whereas a fresh, lush pasture allowed for shorter grazing intervals as they consumed larger quantities within each bite taken.

Time of Supplementation Studies

Knowledge of grazing behaviors provides opportunity to provide supplemental feeding during opportune times. If cattle are supplemented at a time of day that brings them to the bunk from grazing, imperative grazing time is cut short, as once the cattle have filled up on supplement, for 2 to 4 hours after they typically go digest and ruminate (Adams, 1985). If, however, time of supplementation works together to feed in the cycle of the day cattle typically are resting, forage utilization along with average daily gains have potential to be boosted. When self-feeders are implemented, the cattle designate when the most desirable times are to consume the supplement.

Working in accordance with a morning feeding time assumed to be utilized by producers, Barton et. al, (1992) supplemented Holstein steers at 0.25% body weight (**BW**) daily from November to February at 0600 AM or 1200 PM daily, along with a control groups which did not receive supplementation. The AM group had a feeding directly in the typical period of 4 to 8 to interrupt one of the most intensive grazing periods. The PM group fed during a lull in the normal grazing patterns and high ambient temperatures. Barton felt his research was inconclusive and doesn't feel producers should be distressed over time of supplementation to improve cattle ADG.

In a similar study in Montana, 18 Angus × Hereford steers were randomly assigned to a forage only treatment, a group fed a corn at 0.3 kg/100 kg of body weight at either 0730 AM or 1330 PM (Adams, 1985). These cattle were grazed on Russian wild ryegrass from September to

November and again time of feed delivery was chosen to fall during grazing periods or in periods of low activity. The cattle were rotated between all treatment pastures to minimize the differences seen in available forage species within each paddock.

The two studies reported similar results. Adams (1985) reported that the treatment group fed in the AM grazed on average 0.6 and 1.7 hours more per day than both the control group and PM supplemented group. The overall quantity of forage consumed is calculated by considering both the time used to graze, as well as the rate of intake (Arnold and Dudzinski, 1978). Employing this, a 24% decrease in overall forage intake per hour was estimated for the AM group and their grazing intervals shifted to non-traditional times of the day. Although the energy expenditures were not significant between the control group and both the supplementation treatments, there was a tendency for the AM group to be greater than PM. This was associated with the greater time spent grazing and yet almost a quarter less forage intake making the AM supplemented cattle have an overall greater maintenance need (Adams, 1985).

Barton et. al. (1992) reported the control group spent an additional 1.5 hours per day grazing than either of the supplemented groups. As winter progressed, overall grazing hours also increased as a result of snow cover but relationships among treatments remained linear and consistent. Total organic matter intake was significantly different for supplemented cattle over the control group, which was found to be attributed to differences in supplement intake as forage intake was similar across treatments. Interestingly, supplemented steers spent 93% of the time they were grazing with high intensity, which in turn allowed them to be approximately 60% more efficient at utilizing forage intake (Barton et. al., 1992). Although bite size and rate were not accounted for, the extra energy expenditures exhausted by the strictly forage cattle could have added to the differences seen in lighter body weights.

Greater efficiency and lower maintenance costs allowed cattle supplemented in the afternoon to see greater average daily gains across the study. Although all steers in the trial lost weight, those supplemented in Barton et. al. (1992) saw a 35 kg advantage in retained weight when compared to the control cattle. A 32% increase in average daily gain was shown for the afternoon group supplemented than both the AM and non-supplemented group (Adams, 1985). This is credited to the 0.5 and 0.7 Mcal/100 kg body weight greater digestible energy consumed by the PM group. Corn depressed the overall intake in the AM group instead of encouraging additional intake as it did for the other supplemented group (Adams, 1985). Adams' comments on how their research shows small management changes could avoid disrupting the natural grazing bouts leading to significant effects on animal performance (1992). Many trials confirm that supplementing cattle improves overall weight gain. However, the effect of time of day for supplementation on cattle efficiency and average daily gains is inconclusive.

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Chapter II

Effect of time of supplementation on performance and grazing behavior of backgrounded steers

INTRODUCTION

The climate of the southeastern U.S. allows backgrounded cattle to graze stockpiled forage growth into the fall to increase body weight (**BW**) and prepare them for a smooth transition to the feedlot. Backgrounding improves the quality of weaned calves, grants additional time to speculate the cattle market, and allows producers to participate in value-added feeder cattle marketing programs (Thomson and White, 2006). Supplementing backgrounding cattle on pasture improves average daily gain (**ADG**) and prepares them to enter the feedlot by training them to eat out of feed bunks. Horn et al. (1995) suggests a maximum supplementation level of 1.5% of BW so that supplement intake does not replace forage intake and forage is still the main source of overall nutrition.

Sheppard et al. (1957) discussed that the major grazing events for cattle occur from 0400 to 0800 h and from 1600 to 2000 h. Altering or interrupting these patterns could decrease total grazing time and amount of forage consumed, ultimately suppressing ADG. Adam (1985) conducted an experiment that supplemented steers corn at either 0730 h (AM) or 1330 h (PM) and reported that the PM supplemented group had a 32% increase in overall ADG relative to the AM fed group. Allowing cattle ad libitum access to a self-feeder grants the opportunity to observe when they opt to visit the feeder throughout the day, without being conditioned to eat at a specific time of day.

Few experiments have investigated the effect of time or method of supplement delivery on performance and behavior of backgrounding cattle; with none conducted in the Southeastern U.S.

The objective of our experiment was to determine whether steer ADG could be improved simply by feeding supplement between non-typical grazing bouts, instead of disrupting major grazing patterns. Another objective of this experiment was to evaluate the supplemental feed efficiency of hand fed cattle compared to those with access to a self-feeder. The current study examined the influence of supplement feeding time and method on the performance and grazing behavior of backgrounded beef steers hand-fed supplement in the morning or afternoon or given access to self-fed supplement. This would allow for the comparison of supplement delivery methods that either condition cattle to come to the feeder at a specific time of day with handfeeding to a less labor-intensive delivery method that allows cattle to voluntarily consume supplement from a self-feeder throughout the day.

MATERIALS AND METHODS

Animals, Experimental Design, and Treatments

All protocols and experimental methods were approved by the Virginia Tech Institutional Animal Care and Use Committee (IACUC Protocol Number 19-203). This experiment was conducted at the Southwest Virginia Agricultural Research and Extension Center (**AREC**) in Glade Spring, VA from October 1, 2019 to November 8, 2019. A total of 54 crossbred steers were sourced from 4 members of a regional cattleman's association (7 ± 1 month of age; BW = 244 ± 25 kg) and enrolled in the experiment. Steers were crossbred, with majority black coat color with a few black whitefaces, (Angus × Simmental) or grey and white (Angus × Charolais).

Steers were stratified by BW and expected breed composition and assigned to 1 of 9 pasture groups that contained 6 steers. Each pasture group was grazed on a single tall fescue pasture for the duration of the experiment.

Pasture groups were randomly assigned to 1 of 3 treatments (3 pastures per treatment): 1) steers hand-fed supplement at 0930 h (**AM**), 2) steers hand-fed supplement at 1330 h (**PM**), or 3) steers fed a self-feeder supplement with an intake limiter (**SELF**). Hand-fed groups were fed a commercial commodity blend (Southern States Cooperative, Abingdon, VA); 39% corn gluten feed pellets, 30% cracked corn, 22% soy hull pellets, and 10% dried distillers grains) daily at 1.5% BW on an as fed basis. The SELF supplement was a blend of 70% cracked corn and 30% of an intake limiter-containing pellet (Accuration, Purina Animal Nutrition LLC., Gray Summit, MO) that was formulated to maintain voluntary supplement intake at 1.5% BW on an as fed basis to AM and PM groups using a plastic feed trough. Supplement as fed intake for the AM and PM groups was updated based on interim BW recorded on d 11, d 21, and d 30 of the experiment. Each pasture was equipped with an automatic water, so cattle had ad libitum access to water and all treatment pastures were free of trees or other source of shade.

Nutrient composition of supplements is provided in Table 2.1. Steers had free choice access to a commercially available complete mineral mix (Wind & Rain- All Season, Purina Animal Nutrition LLC). with a composition of: 12% Ca (dicalcium phosphate, monocalcium phosphate), 4.0% P (monocalcium phosphate, dicalcium phosphate), 40% Na (salt, sodium selenite), 1% Mg (magnesium oxide), 1.0% K (potassium chloride), 3,600 mg/kg Zn (zinc sulfate), 3,600 mg/kg Mn (manganese sulfate), 1,200 Cu (copper chloride), 12 mg/kg Co (cobalt carbonate), 60 mg/kg I (ferric oxide, ethylenediamine dihydroiodide), 27 mg/kg Se (sodium selenite), 68,039 IU/kg Vitamin A (vitamin A supplement), 6,804 IU/kg Vitamin D (vitamin D3 supplement), and 68 IU/kg Vitamin E (vitamin E supplement).

Steer Management and Performance Measures

Cattle arrived at the AREC over a 2 d period, grazed on common pastures and were acclimated for 6 ± 1 d to consume feed from a feed bunk using the commodity blend supplement used for the AM and PM treatments. The 39 d treatment period began after initial measures of cattle performance were collected over 2 d. Final steer performance data was collected over 2 d at the conclusion of the treatment period. As previously mentioned, 3 interim BW measurements were recorded on d 11, d 21, and d 30 of the treatment period to adjust feeding level of AM and PM hand-fed supplements. After the treatment period ended, steers were returned to their owners or marketed through a value-added, graded feeder cattle sale.

At the start of the treatment period, self-fed cattle were monitored for 72 h to ensure adequate feed consumption. Daily feed for hand-fed cattle was weighed out into buckets, and delivered to the bunk in each pasture. Feed levels and cleanliness of the feed troughs were checked daily for the SELF groups. No feed refusals were observed for any hand-fed treatment groups over the 39 d treatment period. On d 39 all feed left in the self-feeders was weighed back and recorded to properly adjust for overall feed intake for each SELF treatment group.

Steer BW was recorded on two consecutive d on d 0, d 1, d 37, d 39 of experiment. Weights were recorded prior to daily hand-fed supplement delivery to minimize gut fill differences between treatments. Interim BW was recorded every 9 ± 1 d. Cattle were brought up from pastures by treatment groups and weighed in a squeeze chute equipped with weigh bars and a digital scale. Upon completion, cattle were returned to their treatment pasture. Average daily gain and supplement G:F were calculated for the entire treatment period.

Flesh condition score (FCS) was assessed for all steers on d 1 and d 39 by 2 trained individuals in accordance with guidelines described by (Duggin and Stewart, 2017). Each individual assessed FCS individually and the 2 scores were averaged. The scale used was from a score of 1 to 9, with 1 being emaciated and 9 being excessively conditioned. Ultrasound 12th rib fat thickness (**FT**) was measured on days 1 and 39 by a trained individual using an Aloka SSD-500 ultrasound console (Aloka, Wallingford, CT). B-110 mode instrument equipped with a UST-5011 3.5-MHz general purpose transducer array. The distance function of the Aloka SSD-500 was used to measure 12th rib fat thickness. The animal's right side from shoulder to hook bone was clipped to 0.25 cm, vegetable oil was applied to the area, and the probe placed on the area to take transverse orientation measurements between the 12th and 13th ribs approximately 10 cm distal from the midline. Three to five images were taken per animal and the 3 images within 0.07 cm were averaged.

A subset of 2 to 3 calves per pasture group were randomly selected to have an activity monitor (model Zip, Fitbit, San Francisco, CA) temporarily secured to the front, left forearm. The activity monitor was used to record steps taken throughout the day, to measure activity level because the device was not directly intended for cattle. Steps were recorded during the periods between initial, interim, and final weigh dates. The device was wrapped in vet wrap, held on the leg and secured with additional vet wrap around the entire leg. Lastly, tape was placed over the top of the vet wrap to secure it to the leg. Careful attention was paid to ensure blood circulation was not compromised by the wrap being too tightly bound to the leg. At each interim weigh date, the device was removed, each device synced, batteries replaced, and activity monitors were placed on a different steer from a different treatment group. All monitors were rotated between all treatment groups over the 39 d treatment period to minimize individual device effects. Daily animal observations were used to identify animals with noticeably flighty temperaments to avoid placing monitors on steers with poor disposition and prevent biased measurements of activity levels. Animal activity data was excluded for days when activity monitors were placed on and removed from animals so that the activity associated with removing cattle from treatment pastures and restraining them in a squeeze chute would skew the comparison of treatments. In the incident that activity monitors fell off cattle in that pasture, activity for the partial day that the activity monitor remained on the animal was also excluded from the dataset.

One motion-sensing game camera (model D-333, Moultrie Feeders, LLC, Alabaster, AL) was installed per pasture on a post inserted into the ground, with a shade to prevent direct sunlight from causing overexposure of images. Cameras were mounted so that both the feeder and automatic water were in the field of view of each camera so that images of cattle accessing both feeders and waterers were recorded. Cameras were set to capture images in 1 min intervals after motion was detected within a range of 21.3 m. Images were saved and stored on a SIM card by each camera. Data was downloaded every 9 to 10 d to an external hard drive, for subsequent image analysis, and a clean SIM card was inserted to ensure adequate storage space for the next 9 to 10 d period.

Images from 7 d throughout the duration of the treatment period were analyzed for frequency of 4 categories of cattle behavior. Days selected for image analysis were selected in 5 to 7 d intervals with care not to select d that cattle were weighed, to prevent animal interactions before and after weighing from altering normal activity levels.

Pictures were classified into four categories for count data: feeder visits, waterer visits, standing in camera field of view, and lying in camera field of view. Images with feeder visits, showed cattle coming up and putting their head into the bunk to consume feed. Images with waterer visits were those that showed cattle at the waterer and had their head in the trough. Cattle were considered to be standing or lying when they were in the camera field of view doing either activity. It was not possible to quantify the entire time cattle spent standing or lying because of the limited camera field of view; however, investigators analyzed pictures for this activity because it was known that cattle were not grazing at that time. Days were divided into four sections of the day: 0001 to 0600 h, 0601 to 1200 h, 1201 to 1800 h, and 1801 to 2400 h to determine if the distribution of time cattle spent doing each activity differed by treatment.

Feed and Forage Analysis

Samples of each supplement were collected every 10 d for analysis of nutritive value. Forage grab samples were collected every 9 to 10 d of the treatment period for analysis of nutritive value. Feed and forage samples analyzed for nutritive value were dried at 55℃ for a minimum of 72 hto determine dry matter (**DM**) ground to pass through a 1-mm screen, and analyzed in duplicate for crude protein (**CP**), acid detergent fiber (**ADF**), neutral detergent fiber (**NDF**), ether extract (**EE**), and ash. Nitrogen content was measured using an Elementar Vario EL Cube (Elementar Americas Inc., Ronkonkom, NY). Neutral detergent fiber and ADF were determined using an Ankom 200 fiber analyzer (ANKOM, Macedon, NY) following manufacturers guidelines. Ether extract was analyzed using an Ankom XT10 fat extractor (ANKOM) following the manufacturers recommendations.

Forage mass was determined every 9 to 10 d by clipping forage to ground level under three randomly placed 0.10 m^2 plates and drying at 105 ℃ for 72 h.A subsample from each pasture only on d 10 was freeze dried, ground to pass through a 1 mm screen, and sent to Agrinostics for analysis of total ergot alkaloid (**TEA**) content (Agrinostics Ltd., Watkinsville, GA).

Statistical Analysis

Data is reported for 52 steers and 2 excludes steers which died during the trial from unrelated events. One steer from the SELF treatment was removed after complications with a ruminal blockage caused by consumption of a foreign object. One steer was removed from the AM treatment because of kidney failure from overeating acorns prior to arrival at the experiment station. Both steers were removed on d 17 of the study. Average DMI was adjusted to account for the supplement consumed by the cattle while they were on the experiment. Reported DMI from d 1 to d 17 of the treatment period included the 54 steers initially allotted to the experiment; however, reported DMI from d 18 through the end of the experiment included only the 52 steers remaining through the end of the experiment.

All data were analyzed using SAS version 9.4 (SAS Institute Inc., Cary, NC). Pen was considered the experimental unit for animal data. Performance data were analyzed using the MIXED procedure with fixed effects of treatment and pasture total ergot alkaloid level classification to account for difference in fescue alkaloid intake. Total ergot alkaloid concentrations were classified as low (≤, 100 ppb), medium (100 ppb < TEA ≤ 1000 ppb), or high (> 1000 ppb). Means were separated with the pdiff statement when the ANOVA revealed a significant difference between treatments. Forage mass and nutritive value data were analyzed by repeated measures analysis using the MIXED procedure with treatment and pasture included as fixed effects. Behavioral count data were transformed using the log link function and analyzed using Poisson regression in the GLIMMIX procedure with pasture within day considered the experimental unit. The model included the fixed effect of treatment and a random intercept for each pasture to account for the repeated measurements. The least squares means and SEM for count data were back transformed and are reported as the average number of observations per day. Activity data was analyzed using lmer in the lme4 package of R Studio version 1.2.5 (Boston, MA). The model included the fixed effect of treatment, with random effects of period and activity monitor. Step count data were weighted by the number of observations in period divided by the number of possible observations in a period. Treatment effects were considered significant at $P \leq 0.05$ and trends at $0.05 < P \leq 0.10$.

RESULTS

Forage mass data is shown in Figure 2.1. Forage mass was not different between treatments ($P = 0.41$); however, there was a significant effect of sampling date ($P = 0.05$). Forage ash, NDF, and ADF were not different among treatments ($P \geq 0.27$) while CP tended to differ by treatment ($P = 0.08$). Forage, ADF, NDF, CP, and TDN content was significantly different ($P \leq 0.01$) between sampling dates; with ash not differing ($P = 0.79$) by sampling date.

Table 2.1 compares the nutritive values of the self-fed supplement containing an intake limiter to the commodity grain blend of the hand-fed groups. All treatments were formulated at 1.5% of the average weight of pasture group on an as fed basis. The self-feeder blend was 87% DM and the grain mix 88% DM. The greatest differences in the feed nutritive components existed between NDF, CP, and EE. The grain mix was much higher in NDF at 36.83% to 12.04% of the self-feeder mix, as well as a 5% greater CP content. EE was 4% higher in the self-feeder mix at 6.48% to the commodity blend at 2.30% which can be accredited to the greater corn content.

Animal performance data is shown in Table 2.2. Initial BW was not different (*P* = 0.84) by treatment. Final BW and overall ADG were not affected by treatment (*P* ≥ 0.10). Feed efficiency was improved (*P* = 0.03) in the SELF group compared to the AM group and the PM group was intermediate and not different from either. Initial and final 12th rib FT were not different among treatments (*P* ≥ 0.69). Similarly, initial and final FCS were not different among treatments (*P* = 0.11). No differences were detected in treatment ADG from d 1 to d 10 (*P* = 0.52), d 1 to d 20 (*P* = 0.64), or d1 to d 29 (*P* = 0.19). Mean final BW was 283 ± 15 kg and ending FCS was a 5 and not different (*P* = 0.11) between treatments. Final 12th rib FT was not different between treatments (*P* = 0.82); although mean FT did increase numerically from 0.29 to 0.34 cm over the course of the experiment.

Table 2.3 shows the cost of gain per treatment. The price per kg for the self-fed ration of $0.40 was almost double the $0.22 of the commodity blend. Using the above prices per kg of feed. The lowest cost per kg of BW gain was observed for the PM steers at $0.81, with the AM steers being intermediate at $1.00, and the greatest cost per gain in the SELF steers at $1.32.

Table 2.4 shows the relative activity level for cattle placed on each treatment as indicated by daily step count. At the conclusion of the experiment, AM supplemented steers had 1571 steps, PM fed steers had 1606 steps, and the self-feeder steers had 2403 steps recorded per day. Activity level was similar between AM and PM groups but was significantly greater (*P* = 0.05) for the SELF steers.

Behavioral frequency data are shown in Figure 2.3.The greatest significance was seen in the feeder frequency visits between treatments. SELF steers took significantly more trips to the feeder on average than either the AM or PM groups from 0000 to 0600 h, 1801 to 2400 h, and cumulatively for the day. From 0601 to 1200 h the AM and SELF groups visited the feeder significantly more times than the PM group, while from 1201 to 1800 h the PM and SELF groups were similar, visiting significantly more times than the AM group ($P \leq 0.04$).

Cumulative frequency of waterer visits was not significantly different between treatments; but from 0000 to 0600 h the SELF treatment visited significantly more times ($P \leq 0.05$). From 0601 to 1200 h, AM steers visited the waterer significantly more than the other treatments, with neither the SELF or PM cattle similar. In the afternoon from 1201 to 1800 h both PM supplemented cattle and the SELF steers visited the waterer significantly more ($P = 0.03$) than the AM group. A trend was detected ($P \leq 0.10$) for the cumulative frequency of the cattle standing in the camera view with all treatments tending to differ from one another. The SELF steers were observed lying in the camera field of view the greatest number of times per day, differing significantly from both the AM and PM steers, who were significantly different from one another ($P \leq 0.12$).

DISCUSSION

Forage Mass and Nutritive Values

It makes sense that as the cattle grazed the pastures for longer periods of time, forage mass either increased or decreased, along with different weather conditions affecting forage growth. According to Weather Underground (2019) weather records, a total of 6.29 inches of rain were received over 5 days throughout the duration of the experiment. Average temperatures were above the 3-year normal average temperatures for the area with an average of 16°C for the month of October and 6°C for the first 8 days of November to finish the experiment.

Although care was taken to distribute steers among pastures without nutritive differences, the lack of nutrient testing before the experiment began, differences in pasture species composition could explain the trend in crude protein differences. Except for ash, nutritive values were affected by date. This is not unexpected as forage quality would have improved with the late fall regrowth that occurred during much of this experiment. Forage TDN and CP both increased over the course of the experiment, while NDF and ADF both decreased. The warmer weather and addition of moisture allowed the fescue plants to remain green and productive throughout the experiment, similar to results of Hancock and Josey, (2017) who suggest utilizing fescue for fall experiments or grazing, for its ability to hold nutritive value well into the fall.

Animal Performance

There were no differences among treatments at the start of the experiment for either 12^{th} rib FT or FCS. No differences in initial FT or FCE were expected because steers were stratified for BW at the beginning of the experiment and likely had little variation between treatment groups for either measure. Ultrasound measurements were taken to objectively determine external FT, with steers measuring 0.19 to 0.25 cm. The relatively low numbers were expected for the age and growth stage of the steers. All treatments did increase in FT over the duration of the experiment, showing growth potential over time. The FCS of steers ranged from a 4 to 6 both for initial and final measurements. The lack of changes over the duration of the experiment can be accredited to the steers growing but keeping the relationship of flesh to frame size consistent. Feeder cattle with an FCS of 1 and 2 are considered emaciated or extremely thin, and calves with FCS from 6 to 9 are considered too fleshy for most cattle buyers (Duggin and Stewart, 2017). Cattle that fall into either of these extremes are believed to have fallen behind because of insufficient nutrition or feedlots are unable to take advantage of compensatory gains because of extra condition already put on.

Cattle “thriftiness” is an informal quality factor that is decided upon by evaluating a combination of frame score, muscle thickness, and flesh condition scores to predict if backgrounded cattle will develop normally in the feedlot by expectations of growth and carcass merit. This means they do not have any underlying issues in terms of health or physical limitations such as lameness. This is important for marketing to feedlots, who want cattle that have a combination of lean muscle, but still have room on their growth curve to continue with lean growth potential (Duggin and Stewart, 2017). These marketing strategies were proven in work done by Ward et al. (2007) who discussed feeder and backgrounded steer prices, stating that the value of fleshiness was decided depending on whether or not a compensatory gain was expected. Three-year averages showed additional premiums of $1.36/cwt given to thin fleshed calves, while extra fleshy or fat backgrounded steers took a $1.78/cwt discount. The steers in this experiment fell into what is considered to be “thrifty” cattle that offer appropriate lean gain potential based on the condition they began the experiment in.

Previous work has shown that grazing backgrounded steers supplemented at <1.5% of BW allows for greater ADG compared to non-supplemented cattle, without allowing steers to become overly fleshy too rapidly, stunting growth potential. Depositing flesh early does not allow cattle to reach their genetic potential for frame size, limiting additional gains (Horn et al., 1995). In this system, the goal was for steers to derive most of their nutrition from grazing available forages, with supplementation used to improve ADG. Horn et al, (1995) showed an inverse relationship between offering an increasing level of supplementation and decreased time spent grazing by cattle. Steer backgrounding rations were formulated at 1.5% of BW on an as fed basis for this experiment; but final analysis of supplement intake indicated that steers averaged slightly less than this. As fed supplement intake was 1.3%, 1.4%, and 1.5% for PM, AM, and SELF treatments respectively.

With an overall goal of adding BW, supplementing cattle on a predominantly forage-based diet has the capability of improving animal performance, conserving forage to enable a longer grazing period, and ultimately increase return on investment from the purchase price of the cattle (Kunkle, 2000). Deciding frequency of supplementation can consider many factors such as labor availability or the quality of available forage. Offering energy supplementation, as is the case in this experiment, has shown to have a direct relationship between frequency of supplementation and beef cattle performance (Moriel, 2017). In a study done with 218 kg freshly-weaned, crossbred steers, cattle were weaned and offered tall fescue hay and supplemented with a pellet-mix of 50% soybean hulls and 50% corn gluten feed either daily or every 3 d, for a 42 d experiment. The steers were offered the same amount of supplement regardless of number of days per wk supplemented.

Steers supplemented only 3 times per wk had a 0.27 kg/d lower ADG, lower total hay DMI by 24.5 kg, and numerically different feed efficiency for supplemental intake (Moriel, 2017). These results relate to the current experiment by indicating that more frequent feedings improve feed efficiency. This concept makes sense in that steers on the SELF treatment in the current experiment had greater, more desirable supplemental G:F than those in the AM group, while the PM group was intermediate. Final G:F ratio for the SELF steers was 0.328, 0.217 for the AM treatment, and 0.278 for the PM group. Numerically this is a mean gain of 0.10 kg per 0.4535 kg fed for the AM treatment compared to a gain of 0.13 kg per 0.4535 kg supplemented in the SELF cattle. There was a significant advantage shown that the self-fed steers were more feed efficient per kg of supplement consumed.

Although there were only numerical differences between the AM and PM supplemented groups, this lack of differences could be due to the fact that as each treatment was only replicated in 3 pastures. Cumulatively, this experiment and previous research indicates that reducing feeding frequency of energy supplementation during the backgrounding period could hurt overall feed efficiency and forage intake.

The advantage to a backgrounding system is the potential for adding value to beef calves with low feed costs. Duggin and Stewart (2017) discussed that greatest economic returns on backgrounded calves have been realized when feeding locally sourced, inexpensive by-products, or feeds produced on farm to keep inputs as low as possible and increase profit margins. Keeping this in mind, an intake limiter had to be added to the self-fed ration to prevent over-eating, causing the price per ton of rations to be much higher. The corn and intake limiter mix for the self-fed ration was $365 per 907 kg, whereas the grain mix for the AM and PM ration was $200 per 907 kg. Purina Animal Nutrition (2010) claims that their Accuration formula allows for greater cattle forage intake, increased supplementation efficiency, and greater overall performance. In the present study the self-fed cattle were more feed efficient, however no differences in ADG were observed.

The intake limiter was shown to work in limiting cattle to a specified DMI per day, however, the price point in feed costs is much greater. In this experiment it was estimated that it took 0.5 h daily to measure feed, drive to the pastures and deliver feed for hand-supplemented groups. This extra labor and time are saved by the self-feeder only needing to be filled once per wk or less, and depending on what help is paid, can reduce costs greatly for daily inputs however, minimal performance advantages were observed across treatment groups.

Behavioral Differences

Grazing behavior has long been studied in cattle with mixed results from one experiment to the next. Even within single contemporary groups, individual grazing habits and preferences make it difficult to discern a specific pattern that all cattle follow. Sheppard et al. (1957) noted that the largest factors influencing grazing behavior was the overall forage quantity and palatability. This is a direct reflection of climate, season, management practices, other supplementation options, as well as the stage of production of the cattle. Considering this, an objective of the current experiment was to record the number of steps taken daily to discern any activity level differences between treatment groups. The number of recorded steps in the current experiment were low in comparison to those reported in an experiment conducted by Roelofs et al. (2005) who put pedometers on the rear leg of dairy cows in a total confinement barn. The reported average number of steps per day over a 10 d observation period was 4295 ± 2317 for cows in the total confinement barn. Previous research by Walker et al. (1985) used pedometers on the front leg to track cattle movement throughout a pasture and reported average distance traveled of 10.1 ± 3.31 km ·/ d. The differences in step count observed in the current experiment could be associated with using a product intended for monitoring human activity on an animal. The possibility exists that not all steps were documented due to the sensitivity of the activity monitor used. Although activity levels were low relative to other cattle step counts, the significance of the SELF steers having the greatest recorded activity levels agrees with the differences in behavioral frequency data between self-fed and hand-supplemented treatments. It is impossible to directly compare the current experiment with others because of differing pasture and facilities, weather, terrain, and other variables.

Behavioral research that focuses on individual animal movement within a larger group indicates that cattle whose activity variates from the group are theorized to have greater social interactions or are trying to keep distance from the herd based on behavioral hierarchy (Walker et al., 1985). In the experiment conducted by Roelofs et al. (2005), differing number of steps were attributed to things such as distance from the milking parlor or the onset of estrus throughout the observation period. For the current experiment, considering that contemporary group sizes were constant among all pastures, it is hypothesized that after hand-fed cattle were fed, they grazed or rested for the remainder of the day. Self-feeder steers had the ability to revisit the feeder for small interim feedings throughout the day, followed by visiting the water. The possibility that these extra visits could be the reason they had roughly an extra 800 steps per day over the hand-fed groups.

The greatest behavioral differences came in the number of visits to the feeders that were seen between treatments. Self-fed cattle visited the feeder nearly twice the number of times both the AM and PM groups did. This could be the major contributor to the greater number of steps that were taken per day for self-fed cattle as they would have been coming to the feeder to consume numerous, moderately-sized meals throughout the day compared to the single feeding event that took place in the hand-supplemented treatments. Morning and afternoon supplemented cattle visted the feeders when they were supplemented with very few visits between feedings. These treatments were conditioned to consume their feed as a group and without additional reason to come to the feeder, opted to stay away from the feeders. It was difficult to calculate the time spent consuming supplement using the methods employed in the current study. It was difficult to conclusively identify individual animals on the images captured by the motion-sensitive cameras and individual meal events did not have definite start and end time recorded.

Feeding events with a single picture of cattle eating from feeders would have had to be assumed to have a duration of 1 min; when in fact the duration could have ranged from 1 to 119 s when motion was not detected to capture another photo. As a result, the decision was made to only report behavioral data as a frequency data.

Camera frequency analysis for waterer visits resulted in significant differences throughout the day as to when steers were visiting waterers in pastures. Self-fed steers cumulatively throughout the day saw significantly more water visits than either hand-supplemented group, whose visits to the waterer spaced sporadically throughout the day. From 0000 to 0600 h and 1801 to 2400 h, neither the AM or PM supplemented cattle barely visited the feeder, and the SELF steers had significantly more visits during these times. This could be attributed to the small meals taken throughout the duration of the day, followed by intake of water, when neither of the hand-supplemented groups had access to supplement at these times.

The majority of waterer visits took place between 0600 and 1800 h, coinciding with the heat of the day, when cattle were consuming water. The AM supplemented group had the greatest frequency of visits from 0601 to 1200 h being similar to SELF cattle but differed significantly from the PM treatment. This lines up with when their supplement was delivered. In the afternoon from 1201 to 1800 h, the same is true with the PM supplemented steers having the greatest number of water visits, being similar to the SELF cattle, but significantly more than the AM treatment. Again, in line with their time of supplementation.

The frequency of steers lying in front of camera field of view did not differ by treatment during any portion of the day; but, cumulatively the self-feeder cattle were in camera view resting significantly ($P > 0.01$) more times than either the AM or PM steers. The greatest number of observations took place from 0601 to 1800 h, when cattle were seen lying down in line with the cameras. Steers in the SELF treatment tended to lay within camera view even during the night hours from 0000 to 0600 h and 1801 to 2400 h, while the hand-supplemented cattle were elsewhere, out of the camera field of view during that time.

Similarly, steers in the self-feeder groups were observed staying within camera view when having low activity levels. Steers in the SELF treatment tended to spend the most time during a 24 h period standing in line of the camera, with the AM group spending the least, and the PM steers intermediate to both. This means SELF steers were not venturing out to the pasture but instead opting to remain close to the feed and water sources. The greatest differences were seen from 1801 to 2400 h when both AM and PM steers were elsewhere, the SELF cattle remained within camera view for the greatest standing frequency. Although behavior cannot be determined outside of the camera view, it can be speculated that they spent more time grazing and resting on a greater portion of treatment pastures, especially during the night hours of 0000 to 0600 h and 1801 to 2400 h.

Although we cannot definitively say what the steers were doing outside of the camera view, it is apparent that SELF cattle remained closer to the feeder for all behavioral categories, whereas the hand-supplemented groups were out in the pasture away from the feeders and water troughs. Previous research by Rittenhouse L.R., et al. (1970) and Barton et al., (1992) stated cattle that needed to meet greater nutrient requirements associated with an increase in grazing time. It can be speculated that cattle limited to one supplementation time spend the rest of their day grazing in the pastures, compared to the SELF cattle who had the opportunity to consume supplement throughout the day. This previous research supports the results of the current experiment and the hypothesis that altering time of supplementation would affect grazing behaviors and time of day of these behaviors occurred in backgrounded beef steers.

Collectively, the results of the current experiment suggest that altering the time of feeding supplement to grazing backgrounded steers does not have significant effects on overall steer performance, with the exception of supplemental feed efficiency. From a practical standpoint there are opportunities to adjust cattle feeding times without a limiting cattle performance. The experiment showed no significant performance difference between AM or PM supplemented groups. The cost of gain should be weighed to make decisions within individual operations. Having the opportunity to duplicate this experiment over a longer period and with greater treatment replications could improve the ability to detect differences in cattle performance. Additional research is needed to understand whether the performance measures were due to the specific conditions of our experiment or could be duplicated under a variety of environmental conditions to show the need to adjust time of feeding for backgrounded beef calves.

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TABLES & FIGURES

Table 2.1 Nutrient composition of supplemental feedstuffs fed to backgrounded beef steers grazed on tall fescue pastures over 39 d.

Item	Self-fed Supplement[1]	Commodity Blend[2]
DM, % AF	87.0	88.0
CP, % DM	11.9	17.8
NDF, % DM	12.6	39.9
Ash, % DM	2.3	5.7
EE, % DM	6.5	2.3

[1]Self-fed treatment groups fed at 1.5% BW on an as fed basis, were fed a blend of 70% cracked corn and 30% Accuration (Purina Animal Nutrition LLC., Gray Summit, MO) as an intake limiter.
[2]AM and PM groups were fed at 1.5% BW on as fed basis, a blend of 39% corn gluten pellets, 30% cracked corn, 22% soy hull pellets, and 10% dried distillers grains (Southern States Cooperative, Abingdon, VA) at 1.5% of BW on DM basis.

Table 2.2: Performance of backgrounded beef steers grazed on tall fescue pastures and supplemented in the morning, afternoon or given access to a self-fed supplement over a 39 d period.[1]

Item	**Treatments**[2]				***P* – value**[3]		
	AM	**PM**	**Self**	**SEM**	**Treatment**	**AM vs. PM**	**Hand vs. Self**
Initial BW, kg	243	243	243	0.95	0.84	0.80	0.61
Final BW, kg	275	280	296	0.76	0.13	0.50	0.11
ADG d 0-39, kg/d	0.86	1.01	1.33	0.17	0.14	0.40	0.13
Supplement DMI, kg/hd · d^{-1}	3.5	3.3	3.9	0.34	0.53	0.54	0.30
Supplement Intake, %BW as fed basis	1.4	1.3	1.5	0.12	0.62	0.46	0.42
Supplement G:F	0.217[b]	0.278[ab]	0.328[a]	0.028	0.03	0.08	0.08
Initial FCS[4]	5.06	4.65	5.11	0.21	0.22	0.10	0.39
Final FCS[4]	4.86	4.68	5.29	0.24	0.32	0.49	0.16
FCS Change	-0.20	0.03	0.18	0.24	0.29	0.52	0.16
Initial 12th Rib FT, cm	0.21	0.22	0.22	0.02	0.87	0.70	0.88
Final 12th Rib FF, cm	0.30	0.30	0.32	0.02	0.62	0.89	0.37
12th Rib FT Change, cm	0.09	0.08	0.10	0.01	0.18	0.27	0.12

[a-b] Values within a row not sharing a common superscript differ significantly ($P \leq 0.05$).
[1] Body weight = BW, average daily gain = ADG, dry matter intake = DMI, gain to feed = G:F, flesh condition score = FCS, 12th rib fat thickness = FT
[2] Treatments consisted of a commodity blend fed at either 0930 (AM) or 1330 (PM), or a blend of cracked corn with a commercial intake limiter fed *ad libitum* (Self). Values are means of 3 replicate groups of 6 steers each (n = 3 per treatment).
[3] P-values represent the effect of treatment (Treatment) and orthogonal contrast of the AM vs. PM treatment (AM vs. PM) or AM and PM vs. Self-fed treatments (Hand vs. Self).
[4] Flesh condition score was assigned on a scale of 1 to 9. A score of 1 indicates severely emaciated and a 9 indicates excessive fat.

Table 2.3 Cost of gain of backgrounded beef steers grazed on tall fescue pastures and supplemented in the morning, afternoon, or given access to self-fed supplement over a 39 d period.

Treatment	**Feed Cost per T**	**Supplement DM, %**	**Supplement Intake, kg/d, as fed**	**Feed Cost, $ per d**	**ADG kg/d**	**Cost of Gain $/kg**
AM[1]	$200.00	88%	3.90	$0.86	0.86	$1.00
PM[1]	$200.00	88%	3.65	$0.81	1.00	$0.81
SELF[2]	$365.00	87%	4.36	$1.74	1.32	$1.32

[1]Am and PM groups were fed a blend of 38% corn gluten pellets, 30% cracked corn, 22% soy hull pellets, and 10% dried distillers grains (Southern States Cooperative, Abingdon, VA) at 1.5% of BW on as fed basis.
[2]Self-fed treatment groups were fed a blend of 70% cracked corn and 30% Accuration (Purina Animal Nutrition LLC., Gray Summit, MO) as an intake limiter.

Table 2.4 Daily activity level of backgrounded beef steers grazed on tall fescue pastures and supplemented in the morning, afternoon, or given access to self-fed supplement over a 39 d period.

	Treatment[1]				***P*-values[2]**		
	AM	**PM**	**SELF**	**SEM**	**Treatment**	**AM vs PM**	**Hand vs. Self**
Average daily steps[3]	1376[b]	1514[b]	2304[a]	164	0.03	0.39	0.001

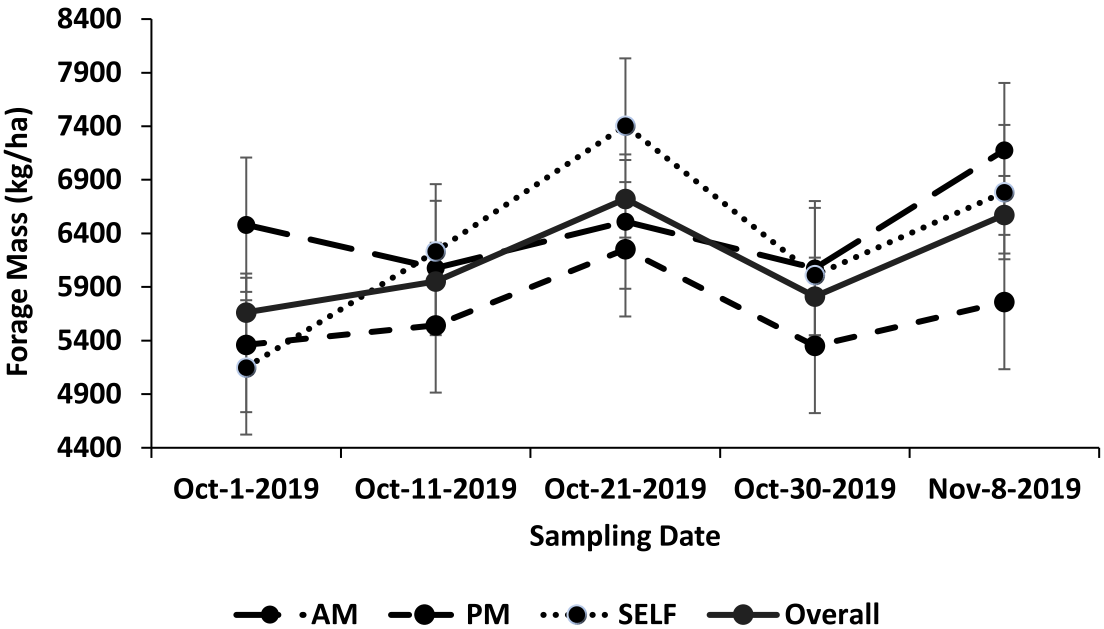
[a,b] Values within a row, values not sharing a common superscript differ significantly ($P \leq 0.05$).

[1]Treatments consisted of a commodity blend fed at either 0930 (AM) or 1330 (PM), or a blend of cracked corn with a commercial intake limiter fed *ad libitum* (SELF).

[2]*P*-values represent the effect of treatment (Treatment) and orthogonal contrast of the AM vs. PM treatment (AM vs. PM) or AM and PM vs. Self-fed treatments (Hand vs. Self).

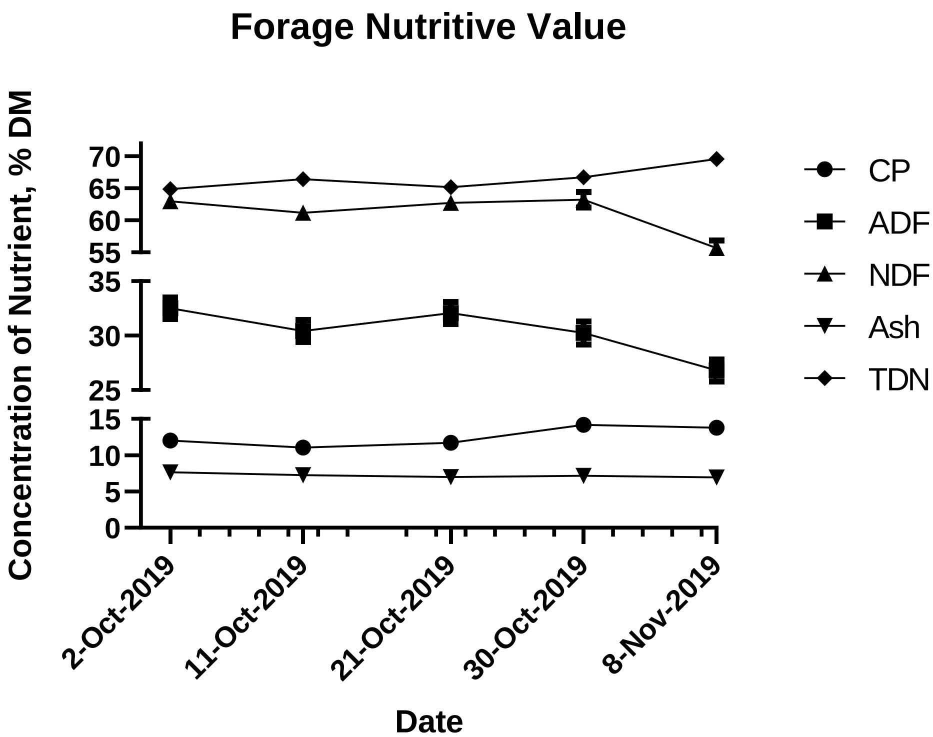
[3]Weighted number of steps recorded by an activity monitor activity monitor (model Zip, Fitbit, San Francisco, CA) placed on the front left leg of grazing steers.

Figure 2.1 Forage mass of tall fescue treatment pastures during the 39 d treatment period.



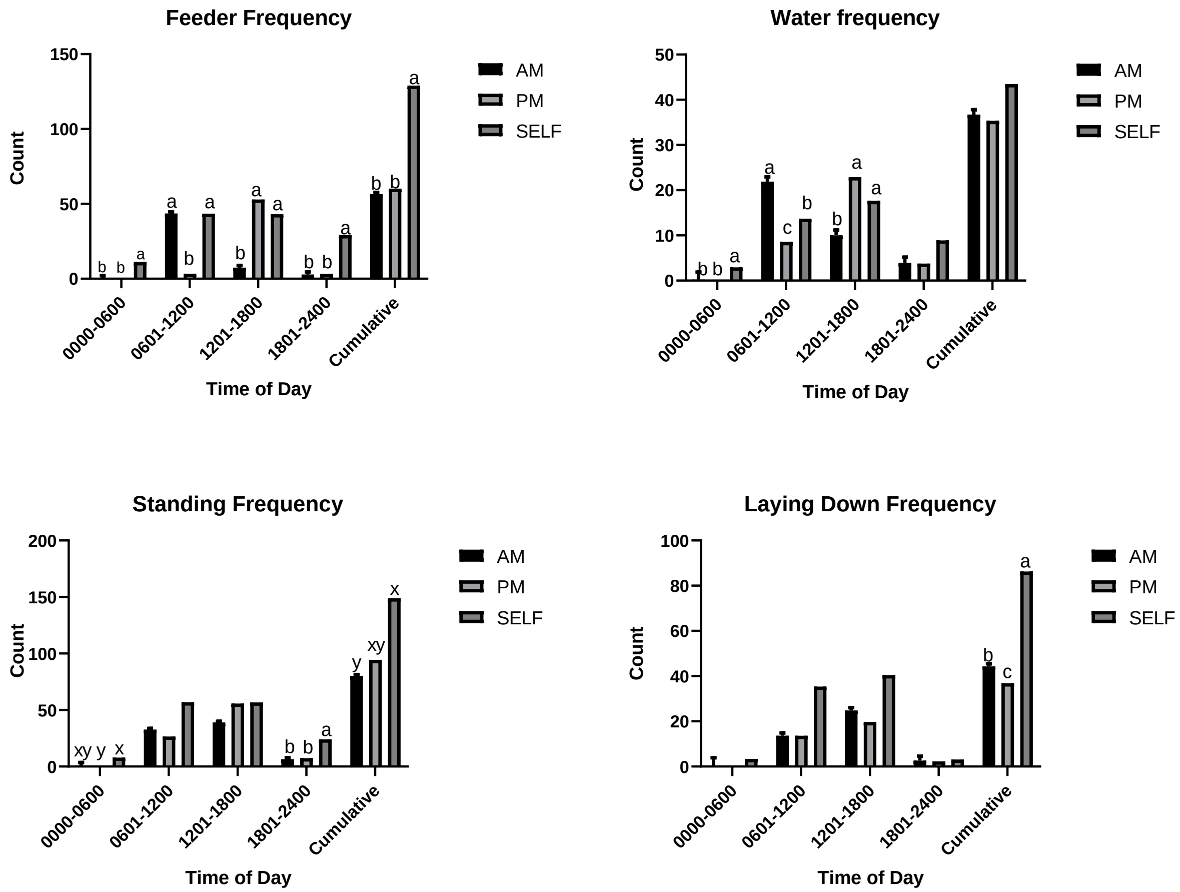
Treatments consisted of a commodity blend fed at either 0930 (AM) or 1330 (PM), or a blend of cracked corn with a commercial intake limiter fed *ad libitum* (Self). There were no differences among treatments (P = 0.41) or sample date × treatment interaction (P = 0.49). Forage mass differed by sample date (P = 0.05).

Figure 2.2: Nutritive value of tall fescue treatment pastures during the 39 d treatment period.



Treatments consisted of a commodity blend fed at either 0930 (AM) or 1330 (PM), or a blend of cracked corn with a commercial intake limiter fed *ad libitum* (SELF). Forage NDF, ADF, CP, TDN differed ($P \leq 0.05$) across sample date. Crude protein tended to be different among treatments ($P = 0.08$). There were no differences ($P > 0.10$) by treatment or sample for ash.

Figure 2.3 Behavioral frequency of backgrounded beef steers grazed on tall fescue pastures and supplemented in the morning, afternoon, or given access to a self-fed supplement for 39 d.[1,2]



[a,b,c] Values within the same time segment not sharing a common superscript differ significantly ($P \leq 0.05$).

[x,y,z] Values within the same time segment not sharing a common superscript tend to be different ($0.05 < P \leq 0.10$).

[1] Values are means of 3 replicate groups over 7 days of 6 steers each (n = 21 per treatment).

[2] Treatments consisted of a commodity blend fed at either 0930 (AM) or 1330 (PM), or a blend of cracked corn with a commercial intake limiter fed *ad libitum* (SELF).

Chapter III

Conclusions

Background and Objectives

Cattle typically graze in two major bouts during the day, one in the morning and one in the evening, to avoid the need to graze during the heat of the day. Traditionally supplemental feedings are delivered to backgrounded cattle in the morning. This practice has been suggested to limit ADG by disrupting grazing activity by causing cattle to stop grazing and come to a feeder consume supplement. The objective of the current experiment was to observe whether steer average daily gain (**ADG**) could be increased by simply delivering supplemental feed at times between typical grazing bouts, to minimize disruptions in natural grazing times. Another objective was to compare performance, behavior, and cost of gain between hand-fed cattle and with those with access to a supplement containing an intake limiter and delivered with a self-feeder. Previous literature provides evidence that cattle supplemented in the afternoon would have greater ADG and performance advantages with G:F than those supplemented in the morning. Cattle with access to a self-feeder were believed to have lower activity levels due to the fact they would remain close to the feeder throughout the day. The objectives of the current experiment were to examine the influence of supplement feeding time and method on the performance and grazing behavior of backgrounded beef steers hand-fed supplement in the morning or afternoon or given access to self-fed supplement. This would allow for the comparison of supplement delivery methods that either condition cattle to come to the feeder at a specific time of day with handfeeding to a less labor-intensive delivery method that allows cattle to voluntarily consume supplement from a self-feeder throughout the day.

Experimental Design

This experiment included 3 treatments: 1) steers were hand supplemented daily in the morning at 0930 h (AM), 2) steers were hand supplemented daily in the afternoon at 1330 h (PM), and 3) steers were offered *ad libitum* access to a self-feeder (SELF). Each treatment had 3 pasture groups of 6 steers each for a total of 54 crossbred steers sourced from four local producers. Steers were stratified by BW, source, and coat color, to ensure no differences in genetic influence of breed and then randomly assigned to 1 of 9 pasture groups. Hand-fed steers were fed a commodity blend (Southern States Cooperative, Abingdon, VA), of 39% corn gluten pellets, 30% cracked corn, 22% soy hull pellets, and 10% dried distillers grain formulated at a rate of 1.5% on a dry matter basis. The self-feeder steers received a blend of 70% cracked corn with 30% of a commercial pellet that contained an intake limiter (Accuration, Purina Animal Nutrition LLC, Gray Summit, MO). The commercial pellet contained a proprietary intake limiter with inclusion formulated to limit intake at 1.5% of BW on an as fed basis. Every 10 d steers were weighed to adjust feed levels to maintain accurate supplement levels.

Flesh condition scores (FCS) were recorded for all steers on d 1 and d 39 by 2 trained individuals according to a bulletin distributed by the University of Georgia, with guidelines and parameters laid out (Duggin and Stewart, 2017) and averaged. The scale used was from a score 1 to 9, with 1 being emaciated and 9 being excessively conditioned. Ultrasound 12th rib fat thickness (**FT**) was measured on days 1 and 39 by a trained individual using an Aloka SSD-500 ultrasound console (Aloka, Wallingford, CT). The animal's right side from shoulder to hook bone was clipped to 0.25 cm, vegetable oil was applied to the area, and the probe placed on the area to take transverse orientation measurements between the 12th and 13th ribs approximately 10 cm distal from the midline. Three to five images were taken per animal and the 3 images within 0.07 cm were averaged.

A subset of 2 to 3 calves per pasture group were randomly selected to have an activity monitor temporarily secured to the front, left forearm. The activity monitor (model Zip, Fitbit, San Francisco, CA) was used to record steps taken throughout the day, to measure activity level because the device was not directly intended for cattle. The device was wrapped in vet wrap, held on the leg and secured with additional vet wrap around the entire leg. Lastly, tape was placed over the top of the vet wrap to secure it to the leg. Careful attention was paid to ensure blood circulation was not compromised by the wrap being too tightly bound to the leg. At each interim weigh date, the device was removed, each device synced, batteries replaced, and activity monitors were placed on a different steer from a different treatment group. All monitors were rotated between all treatment groups over the 39 d treatment period to minimize individual device effects. Daily observations were used to avoid placing monitors on steers with noticeably poor disposition to prevent biased measurements of activity levels from cattle with poor temperaments.

One motion-sensing camera model (D-333, Moultrie Feeders, LLC, Alabaster, AL) per pasture was installed on a post inserted into the ground, with a shade to prevent direct sunlight from causing overexposure of images. Both the feeder and automatic water were in the field of view for each camera to record images of cattle accessing both feeders and waterers. Cameras were set to capture images in 1 min intervals after motion was detected within a range of 21.3 m. Images were saved and stored on a SIM card by each camera. Data was downloaded every 9 to 10 d to an external hard drive, for subsequent image analysis, and a clean SIM card was inserted to ensure adequate storage space for the next 9 to 10 d period. Images from every 5 to 7 selected days throughout the duration of the experiment were analyzed that cattle were not worked, to prevent additional interaction past feeding from altering normal activity levels.

Results

The forage mass and nutritive value had a slightly different CP, but otherwise remained constant among all pasture groups. Limited research has investigated the effect of time of supplementation on cattle performance and grazing behavior; but previous work has shown a positive correlation between increased cattle performance and delivering supplement in the afternoon relative to in the morning. Initial BW was not different by treatment (243 ± 2 kg average) with final BW also not different by treatment (283 ± 13 kg average). No differences were observed for ADG, flesh condition score, or 12th rib fat thickness. However, SELF cattle did have improved G:F relative to AM supplemented steers, with PM supplemented steers being intermediate and not different from either.

The commodity blend for the AM and PM supplemented groups was $200 per 907 kg, while the self-feeder ration was $365 per 907 kg. Based on this, the lowest cost per kg of gain was seen in the PM steers at $0.81, with the intermediate price seen in the AM group at $1.00, and the greatest cost per gain in the SELF steers at $1.32. The intake limiter was shown to work in maintaining cattle to a specified DMI per day, however, the price point in feed costs is much greater. In this experiment it was figured at 0.5 h daily to measure feed, drive to the pastures and deliver feed for hand-supplemented groups. This extra labor and time are saved by the self-feeder only needing to be filled weekly or bi-weekly, and depending on labor rates, can reduce costs greatly for daily inputs however, minimal performance advantages were observed across treatment groups.

Behavioral differences were noted in the number of feeder visits the self-feeder cattle made throughout the day, which was almost double that of either of the hand-fed groups. They also were much more likely to remain within the camera field of view, which meant they stayed close to the feeder and waterer and likely spent less time grazing than the hand-supplemented cattle did. Average daily steps were not different between the AM and PM steers with average steps recorded over 7 randomly selected days during the experiment avoiding any days cattle were worked, of 1,376 and 1,514 respectively. The SELF steers averaged the highest number of steps recorded at 2,304 steps per day.

Conclusions

Although G:F efficiency was better for SELF steers compared to AM but were not different than PM supplemented cattle. The lack of performance differences does not provide a definitive reason to alter supplementation time. Grazing behaviors shift when cattle have the option to visit a feeder for small intermediate sized meals throughout the day, compared to those conditioned to eat one large meal per day as is the case with the hand-fed treatments. It should be evaluated what the input cost budget is and labor available to decide if the added input costs are worth a very slight advantage in feed efficiency. Our findings do show the possibility that a difference in efficiency in AM supplemented cattle relative to PM or SELF fed cattle may exist; but, future research needs to be done over a longer period of time and with additional treatment replications to more thoroughly investigate the effect time and method of supplement delivery has on performance of backgrounded cattle.