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Effect of Backgrounding Management Strategies on the Performance and Profitability of Yearling Beef Cattle

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EFFECT OF BACKGROUNDING MANAGEMENT STRATEGIES ON THE PERFORMANCE AND PROFITABILITY OF YEARLING BEEF CATTLE

by

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EFFECT OF BACKGROUNDING MANAGEMENT STRATEGIES ON THE PERFORMANCE AND PROFITABILITY OF YEARLING BEEF CATTLE

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Performance and profitability of steers grazing smooth bromegrass during the summer was evaluated. Steers grazed bromegrass with no supplement (CON), grazed bromegrass fertilized with 90 kg N/ha (FERT), or grazed bromegrass and were supplemented with distillers grains plus solubles (DGS) at 0.6% of BW (SUPP). Supplemented steers had increased ADG compared to CON and FERT steers. Profitability was greatest for the SUPP steers due to increased ending BW at the end of the grazing season. Steers grazing fertilized pastures were more profitable than CON steers due to increased stocking rate as a result of improved forage growth.

A 2-yr study was conducted to evaluate the effects of summer management strategies on finishing performance and profitability of steers. Treatments consisted of summer finished steers (SHORT), steers grazing smooth bromegrass and supplemented with DDGS at 0.6% of BW (SUPP), steers grazing smooth bromegrass with no supplement (UNSUPP), steers backgrounded in a pen to target ADG of 1.07 kg/d (HI), and backgrounded in pen to target ADG of 0.76 kg/d (LO). Increased ADG during the summer led to decreased DOF to reach equal finish. When compensatory growth was observed, steers backgrounded on pasture were more profitable than steers backgrounded in pens, however, compensatory growth was inconsistently exhibited and therefore may

not be reliable. When fed to equal fat endpoint, steers backgrounded during the summer and finished in the fall had heavier HCW than summer finished steers.

A 2-yr study was conducted to evaluate the effect of different grazing intensities and stocking method on steer performance and animal gain/ha. Treatments consisted of steers continuously grazing smooth bromegrass and initially stocked at either 6.82 AUM/ha (LO) or 9.88 AUM/ha (HI) or steers rotationally grazing smooth bromegrass and initially stocked at 9.88 AUM/ha. Grazing strategy did not affect animal gain or gain/ha. Emphasis should be placed on managing an appropriate grazing intensity, rather than grazing method.

Three studies were conducted to evaluate the effects of supplementing cattle consuming forage diets with pellets containing CaO-treated corn stover and drymilling byproducts on animal performance. As supplementation rate with the pellet increased, so did ADG, while forage DMI decreased.

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A LITERATURE REVIEW:

Supplementation in Forage Based Diets

Moore et al. (1999) constructed a database to describe and estimate the effects of supplementation on cattle consuming high forage diets. In general, the greatest ADG responses to supplementation occurred with improved, non-native, forages, energy supplements containing 60% TDN or greater, and when supplemental CP intake was greater than 0.05% of BW. Additionally, there was variation in ADG response to similar amounts of TDN or CP provided by supplements. Greatest responses in ADG occurred when supplemental energy was provided to calves consuming low quality forages. In relation to RUP supplementation there were also lesser increases in ADG for TDN supplementation at a similar level, illustrating that in most forage settings, protein is the first limiting nutrient for growing cattle. Moore et al. (1999) also evaluated the effects of supplementation on voluntary forage intake and reported that in general, as supplementation rate of calves consuming improved forages increases, voluntary forage intake decreases. However, as supplementation rate of calves consuming lower quality native forage and residues increased, there were instances when forage intake both increased and decreased. The authors attributed the discrepancy in intake response for calves consuming low quality forages to TDN:CP ratios in those forages. When supplementation increased forage intake, the basal forage TDN:CP ratio was greater than 7, signifying that the forage was nitrogen deficient. In these instances, supplemental

nitrogen increased microbial efficiency and digestion of forage, thereby increasing passage rate and consequently intake.

Kunkle et al. (2000) completed a review on designing supplementation programs for cattle consuming forage-based diets. The authors reported that the most common supplementation program is to meet the basal forage diet's protein, mineral, and vitamin deficiencies and then provide supplemental energy if it results in a positive return over cost. In grazing situations, when the primary energy substrate provided by the supplement is comprised of starch, forage intake and digestibility are decreased when supplement is provided over 0.4% of BW. Therefore, providing an energy source low in starch may be beneficial.

In the Corn Belt, DGS provide a source of both protein and energy in a non-starch form. Historically, DGS have also been priced below corn on an equal moisture basis. Ahern et al. (2016) evaluated the feeding value of DGS relative to corn when supplemented to cattle consuming forage-based diets. Ahern et al. (2016) reported that DGS had a feeding value of 136% the value of corn. Additionally, Ahern et al. (2016) reported that there were no differences in feeding value of wet or dry DGS in forage-based diets, which affords producers flexibility in which form of DGS to use.

Corrigan et al. (2009) fed DDGS at increasing levels of 0.25, 0.50, 0.75, or 1.0% of BW to steers (initial weight = 275 kg) consuming a basal diet of 60% alfalfa hay and 40% sorghum silage. As level of DDGS supplementation increased, there was a linear increase in ADG. Likewise, Morris et al. (2005) fed DDGS to heifer calves consuming either a high (similar to Corrigan et al., 2009) or low quality (bromegrass hay) forage diet

at approximately 0, 0.15, 0.60, or 0.80% of BW. In both diets, as rate of supplementation increased, there was a linear increase in ADG. In addition, Corrigan et al. (2009) and Morris et al. (2005) reported that as supplementation rate increased, forage intake decreased. This possibly allows for increased stocking rate in grazing situations due to the substitution of supplement for forage (MacDonald et al., 2007).

Economics of Supplementation on High Quality Forages

Even though supplementation may result in a gain response, the additional gain may not offset the additional costs incurred due to supplementation. Scaglia et al. (2009) conducted a study to evaluate the effects of supplementation on performance and profitability of beef steers grazing ryegrass. Steers (BW = 228 kg) grazed ryegrass with no supplement or were supplemented with corn gluten feed at 0.5% of BW in the morning. Supplemented steers had numerically greater ADG (1.34 vs. 1.20 kg/d) and gain per hectare (755.5 vs. 701.2 kg/ha) compared to the unsupplemented steers, though gains did not differ statistically. However, profitability was numerically greater for unsupplemented control steers ($28.38/steer) compared to supplemented steers ($13.38/steer). The authors, also reported that forage mass at the end of the grazing period was greater for supplemented steers compared to control steers. This is likely due to a substitution effect as a result of supplementation (Moore et al., 1999). Therefore, if supplemented steers had been stocked at a higher rate, thereby decreasing land rental costs, profitability of supplementation may have been greater.

Watson et al. (2012) evaluated the effect of 3 management strategies and their effect on performance and profitability of yearling beef steers grazing bromegrass over a

5-year period. Steers grazed bromegrass, grazed fertilized bromegrass (90 kg N/ha), or grazed bromegrass and were supplemented with DDGS at 0.6% of BW. To account for substitution effects due to supplementation, supplemented steers were initially stocked at 9.88 AUM/ha compared to 6.82 AUM/ha for the controls. Likewise, steers grazing fertilized pastures were stocked at the same rate as the supplemented steers due to increased forage quantity but similar nutritive value. Watson et al. (2012) utilized a variable stocking rate to maintain similar residue height among treatments, thus, actual stocking rates of the three treatments were 8.53, 12.88, and 13.27 AUM/ha for the control, fertilized, and supplemented treatments, respectively. Additionally, supplemented steers gained 0.26 kg/d more than the control and fertilized treatments over the approximately 156 d grazing season; resulting in 40 kg heavier ending BW. Due to increased BW sold and decreased costs associated with pasture rent, supplementing steers resulted in $23.75/steer greater profit than control steers and $26.26/steer greater than fertilized treatment steers.

When supplementing cattle consuming high quality forages, economically beneficial responses to rumen degradeable protein (**RDP**) or rumen undegradeable protein (**RUP**) supplementation alone are often not observed, due to the high protein levels already present in the forage (Paterson et al., 1994; Vendramini and Arthington, 2008). However, energy supplementation can lead to increased ADG of calves along with the ability to utilize higher stocking rates as a result of forage substitution, thereby offsetting some of the costs associated with pasture rent (Lomas et al., 2009; Watson et al., 2012; Lomas et al., 2017)

Yearling Production Systems

Feed costs over the animal's life represent the largest expense in beef production systems (Anderson et al., 2005). Ruminants have the unique ability to convert cellulose from forage and byproduct feedstuffs into energy and protein that the animal can put toward productive use (Van Soest, 1994). During the last decade, price variability of grains has increased; therefore, utilizing cellulosic feeds for as much of the animal's growth as possible may be a method to increase profitability. The use of forage based growing systems can decrease time spent in feedlots consuming grain based diets. Additionally, the majority of beef calves in the United States are born in the spring, however, demand for beef products is year round. Thus, cattle must be slaughtered year round. Here again, the use of forage based growing systems can be of benefit by altering the finishing and marketing window of cattle to create a more constant supply of beef. Additionally, lighter framed cattle benefit from an increased backgrounding period which can increase weight at finishing.

As outlined by Griffin et al. (2007), the two main beef systems types can be broken down into intensive and extensive production. Intensive programs are characterized by the use of calf-fed animals in which the animal is placed into the feedlot directly after weaning (approximately 8 months of age) and fed a grain based concentrate diet until reaching a desired fat endpoint after which they are slaughtered. Extensive production systems are characterized by the use of forage based growing systems in which calves continue to utilize forages after weaning until they are placed in the feedlot, typically around 14 to 17 months of age. In extensive systems, cattle are backgrounded

through the winter on grazed or harvested forage. Following winter, calves can enter the feedlot as short yearlings or continue to be grown through the summer on grazed forages and enter the feedlot in the fall.

Because the population of cattle being weaned in the fall is variable, in terms of size and BW (Dolezal et al., 1993), the use of intensive or extensive productions systems allows for separating calves into the most appropriate management group. Larger calves at weaning can be placed directly into the feedlot while smaller calves can be grown further using forages. Appropriate placement of cattle is important in order to maximize profit. If larger cattle are placed into an extensive system at weaning, the potential for overweight carcasses at slaughter increases which can lead to discounts (Viselmeyer, 1993). Conversely, if smaller cattle are placed directly into the feedlot at weaning, there is the risk of those cattle reaching the desired endpoint at a lighter than desired BW, thus not realizing their full profit potential.

The use of differing production systems, in addition to changing marketing windows and maintaining a year round beef supply, also affects the final carcass characteristics of the animal. Griffin et al. (2007) analyzed the performance and carcass characteristics of calf-fed (intensive) and yearling (extensive) cattle in relation to one another in addition to evaluating the economics of each system. Griffin et al. (2007) utilized performance data of cattle over 8 years in which cattle were bought in the fall at weaning and separated into intensive and extensive systems based upon size and BW, as previously discussed. In that dataset, the average difference in BW between the two systems at receiving was 52 kg. However, due to increased time spent growing prior to

being placed in the feedlot, yearling cattle had 144 kg heavier BW than calf-feds when they began the finishing phase. This increase in initial BW led to increased final BW (38 kg) and decreased DOF (78 d less) for yearlings compared to calf feds. Additionally, yearling cattle had increased ADG compared to calf-feds, although feed efficiency was decreased. While yearlings also had increased DMI compared to calf feds, because they spent fewer days in the feedlot, total feed consumption while in the feedlot was also decreased. When analyzing carcass characteristics, yearlings had increased HCW compared to calf feds but there were no differences in marbling score, quality grade, or yield grade. This comparison highlights the importance of comparing cattle at an equal desired endpoint.

Schoonmaker et al. (2002) also evaluated the effect of calf-fed or yearling systems on finishing performance and carcass characteristics of calves. In agreement with Griffin et al. (2007), Schoonmaker et al. (2002) reported that in comparison to calf-feds, yearling cattle had greater ADG and DMI during the finishing phase along with decreased feed efficiency. The authors were also in agreement that yearling cattle had increased HCW compared to calf-feds, however, Schoonmaker et al. (2002) reported that yearling cattle had decreased quality grade compared to calf-feds with 48.1% of yearlings grading Select while calf-feds only had 12.9% of cattle grade Select. The difference between the two studies then is that in Schoonmaker et al. (2002) randomly assigned cattle to treatment, regardless of BW, whereas the cattle analyzed by Griffin et al. (2007) were assigned to production system according to BW so that the cattle were appropriately matched to the correct production system.

In order to determine if assignment of cattle based on BW truly has an effect on performance and carcass characteristics of cattle, Adams et al. (2010) conducted a study in which steers were placed into either an intensive or extensive production system based upon BW or random assignment. Additionally, the extensive system was broken down into two categories, either summer finished short yearlings that entered the feedlot after winter backgrounding or traditional long yearlings that grazed during the summer as well before being placed into the feedlot. Similar to Griffin et al. (2007) and Schoonmaker et al. (2002), Adams et al. (2010) reported that yearlings, both summer and fall finished, had greater ADG than calf-feds and decreased feed efficiency. However, Adams et al. (2010) reported that regardless of being sorted by BW prior to assignment to production system, there were no differences in quality grade, although calf-feds and fall finished yearlings had greater marbling scores than summer finished yearlings. Similar marbling scores for fall finished yearlings and calf-feds is in agreement with Griffin et al. (2007). However, for both sorted and unsorted cattle, calf-feds and summer finished yearlings had greater 12^{th} rib fat. Therefore, if fed an to equal fat endpoint, it is likely marbling would have increased, but to what degree is uncertain. Of note, Adams et al. (2010) reported that fall yearlings in the unsorted system had a greater incidence of overweight carcasses. This likely would have been further exacerbated if the fall yearlings had been fed to equal 12^{th} rib fat. In addition, unsorted calf-feds also had HCW that were 15 kg lighter than sorted calf-feds. The differences between the two are clearly a result of the sorted cattle being appropriately assigned to the correct production system, whereas the unsorted cattle were not. Also in agreement with Griffin et al. (2007), Lancaster et al.

(2014) completed a meta-analysis evaluating effects of calf-fed and yearling systems on finishing performance and carcass characteristics and they reported no differences in marbling scores between calf-feds and yearling steers.

Overall, yearlings are heavier at feedlot entry and have increased DMI (kg/d) and ADG but decreased G:F. Additionally, yearlings finish with greater HCW after less DOF while maintaining similar QG and YG (Shain et al., 2005; Tatum et al., 2006; Griffin et al., 2007; Adams et al., 2010; Lancaster et al., 2014). The key, however, in assigning cattle to the appropriate production system is to take into account size and physiological maturity. As calf-feds and yearlings have similar carcass quality at slaughter, the use of an extensive yearling system gives the opportunity to increase weight sold while not incurring discounts associated with decreases in carcass quality or increases in overweight carcasses, if cattle are managed correctly (Klopfenstein et al., 1999). Therefore, in areas where there is an availability of cheap winter and/or summer grazing resources, yearling production systems may be beneficial to maximize profit potential. In conjunction with the use of available grazing resources, the use of ethanol byproducts to supplement cattle in yearling production systems can also increase profitability of the system (Watson et al., 2012). In Nebraska, a common yearling production system would consist of grazing corn residue from weaning until April, upon which cattle can either be placed in the feedlot or grown further on either native range or improved cool season grass until September, at which point they would then enter the feedlot. Distillers grains plus solubles (**DGS**) is commonly used as a supplement to cattle during these different phases of yearling production.

Supplementation of Yearling Cattle

Winter

In Nebraska, there is an abundance of corn residue which provides a relatively inexpensive source of grazable forage (Klopfenstein et al., 1987). However, corn residue is also low in both energy (53.6% TDN) and protein (6.1% CP; NRBC, 2016). Additionally, corn residue is unique in that all the available forage is present at the beginning of grazing and from then on is in decline due to consumption. In addition to the decline of available forage as grazing time progresses, so does corn residue quality due to grazing selection and weathering (Yerka et al., 2015). Fernandez-Rivera et al. (1989) reported that as grazing time progressed, crude protein content and in vitro dry matter disappearance declined. Therefore, in order to achieve desired gains, it is necessary to supplement growing cattle with a source of both energy and protein. Illustrating that point is a trial by Tibbitts et al. (2016) in which a control group of steers (initial BW = 234 kg) grazing corn residue with no supplement lost 0.08 kg of BW per day. Tibbitts et al. (2016) also reported that calves supplemented with a source of RUP had increased ADG compared to calves fed a supplement supplying an equivalent amount of TDN in which RDP requirements were met, emphasizing the importance of a source of RUP in addition to RDP for growing calves to have optimal gains.

Gustad et al. (2006) supplemented 120 steers calves (initial weight = 232 kg) with dried distillers grains plus solubles (**DDGS**) at 0.29, 0.49, 0.69, 0.88, 1.08, or 1.27% of BW. As supplementation rate increased, there was a quadratic increase in gain as ADG increased at a decreasing rate from 0.41 kg/d at 0.29% of BW to 0.82 kg/d at 1.27% of

BW. Jones et al. (2014) supplemented steers grazing corn residue with DDGS or modified distillers grains plus solubles (**MDGS**) at either 0.3, 0.7, or 1.1% of BW. Similar to Gustad et al. (2006), Jones et al. (2014) reported that as supplementation rate increased, ADG increased quadratically.

Jones et al. (2015), however, reported a linear increase in ADG when steer calves grazing corn residue were supplemented with DDGS at 0.3, 0.5, 0.7, 0.9, or 1.1% of BW. Gustad et al. (2006) attributed the quadratic response for ADG to refusals of supplement observed for calves supplemented at 1.27% of BW. Therefore, the authors suggested a supplementation rate of 1.1% of BW as a practical limit. Jones et al. (2014) also attributed the quadratic response in ADG to refusals observed for calves supplemented at 1.1% of BW, however, Jones et al. (2015) did not experience refusals for calves supplemented at 1.1% of BW and thus observed a linear increase in ADG.

Klopfenstein et al. (1999) emphasized the need for not only considering the benefits of corn residue grazing by itself but also as an important component of the yearling system in the Midwest. The use of corn residue as affordable winter grazing allows for continued growth of calves outside the feedlot on summer forages the following year prior to entering the feedlot.

In a 2-year study, Bondurant et al. (2016) evaluated differing levels of supplementation for heifers grazing corn residue prior to grazing summer range and subsequent finishing with the objective of determining which level of winter supplementation had the greatest carryover effects on profitability of the entire yearling system. Bondurant et al. (2016) supplemented heifers with either 1.36, 2.27, or 3.18 kg of

MDGS per heifer daily while grazing corn residue. In both years, there was a linear increase in ADG as level of winter supplement increased. However, in year 1, due to poor performance during the summer as a result of drought, the heifers supplemented at the lowest level were the most profitable. In year 2, the heifers supplemented with the highest level of MDGS had the greatest profitability. While it is impossible to predict environmental conditions, this illustrates the importance of evaluating supplementation rates as part of the entire ownership period and not just in isolation.

Summer

Contrary to winter grazing on corn residue, summer grazing on either native range or improved cool season grasses does not require supplementation in order for the animal to have positive weight gains. However, it is well documented that supplementation of grazing cattle with DGS can increase ADG (Griffin et al., 2012).

Watson et al. (2012) compared unsupplemented yearling steers grazing bromegrass with yearlings receiving DDGS at 0.6% of BW daily. Watson et al. (2012) reported that supplemented cattle gained 0.26 kg/d more than unsupplemented cattle (0.94 compared to 0.68 kg/d). This led to supplemented cattle being 40 kg heavier at the end of the grazing season. Supplementation with DDGS also allowed for greater stocking rates. For every 1 kg of DDGS supplemented there was a replacement of 0.79 kg of forage.

Morris et al. (2006) supplemented yearling steers grazing native Sandhills range during the summer with DDGS at either 0, 0.26, 0.51, 0.77, or 1.03% of BW. As DDGS

supplementation rate increased there was a linear increase in ADG for the summer grazing season. Morris et al. (2006) also predicted forage intake for each rate of DDGS supplementation and similar to Watson et al. (2012), as rate increased, forage intake decreased, thereby allowing for greater stocking rates.

Stalker et al. (2012) evaluated the effect of supplementing 2.3 kg DM of DDGS daily compared to unsupplemented cattle when both were stocked at double the normal rate. Supplemented cattle gained 1.14 kg/d while unsupplemented calves gained 0.45 kg/d, an increase of 0.69 kg/d. The decrease in forage intake of supplemented cattle was less than reported by Watson et al. (2012) and Morris et al. (2006). Therefore, intake was insufficient to result in forage removal equal to the recommended stocking rate.

Supplementation of yearling cattle with DGS increases ADG and decreases forage intake, although the forage intake response has been variable. Therefore, supplementation may allow for increased stocking rates. When rent prices for pasture are high, the decrease in rent costs associated with increased stocking rate can make up for the cost of supplementation (Watson et al., 2012). However, as previously discussed, it is important to evaluate the effects of supplementation, not only within specific phases of production, but in relation to the entire production system. Therefore, it is important to evaluate studies in which subsequent performance is recorded to determine if supplementation is viable not only for a certain phase, but for the entire length of the production system.

Compensatory Growth

Bohman (1955) defined compensatory growth (alternatively gain) as the accelerated and/or more efficient growth that commonly follows a period of growth restriction. In relation to yearling production systems, this restriction would be due to deficiencies in energy and/or protein provided by the forages the cattle are consuming after weaning and prior to feedlot entry. Drouillard et al. (1991) evaluated the effects of both energy and protein restriction along with differences in severity of restriction. The authors reported that steers which were severely energy restricted for 77 d had ADG that were 0.29 kg/d less than steers which were only mildly restricted for the same length of time, but then gained 0.37 kg/d more during the 81 d finishing period and were 40% more feed efficient. For protein restricted steers, differences in ADG during both the restriction period and finishing period were insignificant, along with differences in feed efficiency during the finishing period regardless of severity. In general, gains for protein restricted steers were less than those of energy restricted steers during the restriction period and thus entered the finishing phase at a lighter BW and required a longer feeding period. However, at finish, protein restricted steers also had heavier HCW with no differences in QG or YG. The authors concluded that severe restriction of energy led to improved finishing performance due to compensatory growth; however, protein restriction of animals had little to no effect on subsequent finishing performance.

Although the exact mechanism by which compensatory growth occurs isn’t fully elucidated, it appears to be due to a combination of factors. Fox et al. (1972) attributed the compensatory growth response in restricted animals to increased efficiency of energy

and protein utilization. Horton and Holmes (1978) reported that increases in gain for restricted cattle were primarily due to increases in intake for the restricted cattle. However, similar to Fox et al. (1972), Meyer et al. (1965) reported that increases in compensatory growth were due to increases in energy utilization, independent of intake. Other research has reported that nutrient restriction results in decreased visceral organ mass (Sainz and Bentley, 1997). Therefore, the combination of increased energy utilization, decreased organ mass, and increased intake are likely what lead to increases in gain that are classified as compensatory growth.

Effect of Winter Supplementation on Compensatory Growth of Yearlings

Downs et al. (1998) evaluated the effect of winter gain on subsequent summer grazing (Sandhills range or bromegrass) and finishing performance. Steers were managed to gain either 0.32 or 0.77 kg/d during the winter which lasted 163 d. Summer gains were 0.87 kg/d for the low gain steers and 0.75 kg/d for the high gain steers when grazing Sandhills range. Gains for the low and high winter gain steers grazing bromegrass were 0.33 and 0.22 kg/d, respectively. The increase in summer grazing ADG for the low gain steers allowed them to compensate for 19.9% and 18.7% for the range and bromegrass cattle, respectively. Subsequent finishing ADG, however, was greatest for steers supplemented at the higher rate of gain during the winter. The authors concluded that supplementing at the higher rate of gain during the winter was beneficial, as it led to those steers maintaining 80% of their weight advantage over steers grown at a low rate of gain. Steers wintered at a high rate of gain also required fewer days to finish, thereby decreasing finishing costs.

Jordan et al. (2000) also evaluated the effect of winter gain restriction on subsequent summer and finishing gains as well as its effect on forage intake during the summer. Jordan et al. (2000) reported that steers wintered at a higher rate of gain had decreased ADG during the summer and decreased intake compared to steers wintered at a lower rate of gain. However, at the end of the summer grazing period, steers wintered at a high rate of gain still had increased BW in comparison to low winter gain steers. Jordan et al. (2000) also reported that at equal days on feed in the finishing period, high winter gain steers had greater HCW than low winter gain steers.

As previously discussed, Bondurant et al. (2016) evaluated three levels of MDGS supplementation to heifers grazing corn residue throughout the winter. During the summer of year 2 while grazing Sandhills range, when there was no drought, heifers supplemented with the lowest amount of MDGS during the winter had the greatest ADG, however, the increased summer gains were not enough to offset the weight advantage resulting from increased level of MDGS supplementation during the winter. Increased MDGS supplementation in the winter led to increased HCW at slaughter (372 vs. 385 and 388 kg for the low level compared to the medium and high levels, respectively).

Clearly, there is a benefit to supplementing yearling cattle with some form of additional protein and energy. Furthermore, research would suggest that higher levels of gain during the winter are not offset by increased summer gains of cattle wintered at a lower level of gain even when compensatory growth is exhibited. Therefore, at the conclusion of the finishing period, yearlings wintered at a higher level of gain had increased HCW.

Effect of Summer Supplementation on Compensatory Growth of Yearlings

Greenquist et al. (2009) evaluated the effect of DDGS supplementation of yearling steers grazing bromegrass over a 3-year period. Steers grazed bromegrass with either no supplement or supplemented with DDGS at 0.6% of BW (DM-basis). Greenquist et al. (2009) reported that supplemented steers gained 0.92 kg/d compared to 0.68 kg/d for the unsupplemented cattle, resulting in supplemented cattle being 37 kg heavier at the end of the summer grazing period. Finishing ADG was not different between treatments which led to increased HCW of supplemented steers when killed at equal DOF. Unsupplemented steers had less backfat at slaughter than supplemented steers, therefore if finished to an equal fat endpoint, the difference in HCW may have been made up, but the supplemented cattle would have decreased finishing costs as a result of requiring fewer DOF.

Lomas and Moyer (2008) supplemented yearling steers grazing bromegrass with DDGS at either 0, 0.5, or 1.0% of BW over a 3-year period. During the summer, there was a linear increase in ADG as supplementation rate increased. In the first 2 years of the study, there were no significant differences in ADG during the finishing phase, therefore when finished for an equal number of days, supplemented steers had greater HCW, although there were no differences between steers supplemented at 0.5 and 1.0% due to non-significant differences in ADG during the finishing phase. In the third year of the study, however, the steers that received no DDGS during the summer had greater ADG than the two supplemented treatments. However, at slaughter, supplemented steers still had heavier HCW. The authors concluded that supplementation of yearling steers at 0.5%

of BW was most efficient because even though supplementing at 1.0% of BW increased summer ADG in some years, HCW was no different in any year.

Funston et al. (2007) and Griffin et al. (2012) both conducted studies in which DDGS was fed ad libitum to steers (average 1.45% of BW) while they grazed native range (Funston et al., 2007) or supplemented at 0.6% of BW while grazing cool-season meadow (Griffin et al., 2012) in the Sandhills. Both authors reported that supplementation of cattle with DDGS increased summer ADG (0.39 and 0.14 kg/d for Funston et al., 2007 and Griffin et al., 2012, respectively) and therefore BW entering the feedlot. This increased BW was then maintained throughout the finishing period. In agreement, Rolfe et al. (2011) reported that while unsupplemented steers tended to have greater ADG during the finishing phase than steers supplemented with MDGS at 0.6% of BW during the summer, supplemented steers were more profitable because they required 24 fewer DOF to reach an equal endpoint due to entering the feedlot weighing 48 kg greater than unsupplemented cattle.

Supplementation of yearling steers during the summer leads to increased ADG and ending BW and decreased DOF to reach an equal fat endpoint. Additionally, exhibition of compensatory gain is not consistent, and when exhibited does not completely compensate for the entire amount of BW difference, similar to research evaluating compensatory gain following winter supplementation.

Effect of Winter and Summer Supplementation on Compensatory Growth of Yearlings

The research discussed previously indicates that supplementation during both the winter and summer is beneficial to overall calf performance. However, it is important to note that supplementation during the winter followed by supplementation during the summer was not discussed. Gillespie-Lewis et al. (2016) conducted a 2-year study to determine if there was an interaction between winter and summer supplementation and the effects on finishing performance and carcass characteristics. Each year heifers were supplemented with either 0.91 or 2.3 kg DM of MDGS during the winter while grazing corn residue. In the summer while grazing Sandhills range, heifers either received no supplement or MDGS at 0.6% of BW daily. In year 1 and 2, supplementation with 2.3 kg of MDGS increased ADG by 0.11 kg/d over the winter and summer compared to heifers supplemented with 0.91 kg of MDGS. In year 1, summer supplementation increased ADG by 0.09 kg/d compared to control heifers, and by 0.06 kg/d in year 2. Finishing ADG, however, was decreased by 0.21 kg/d due to summer supplementation in year 1 as a result of compensatory growth by unsupplemented heifers. In year 2, there were no differences in finishing ADG due to treatment. Feed efficiency was not affected by winter supplementation rate in either year but was reduced with summer supplementation in both years. In year 1, due to differences in finishing ADG as a result of compensatory growth, heifers wintered on a greater amount of MDGS but received no supplement during the summer had heavier final BW than heifers wintered at a similar level and supplemented during the summer. However, in year 2, both winter and summer supplementation increased final BW.

Creighton et al. (2003) also evaluated differing levels of winter gain and summer supplementation. In agreement with Downs et al. (1998) and Jordan et al. (2000), the authors reported that steers wintered at a high rate of gain had decreased ADG during the summer but similar ADG during the finishing phase. Additionally, increased summer ADG for the steers wintered at a lower rate of gain during the summer could not offset the BW advantage of the steers wintered at a higher rate of gain and therefore had lighter final BW. Summer supplementation with 1.3 kg DM, three times a week (0.56 kg/d), however did not significantly increase summer ADG and led to no differences in finishing ADG or final BW.

This research demonstrates that supplementing at higher levels during the wintering phase increases BW of calves. Most weight is maintained throughout the rest of the production cycle. The efficacy of summer supplementation following winter supplementation; however, is inconsistent. However, compensatory growth is not uniformly exhibited across all years, even within individual experiments. Research would suggest that compensatory growth is influenced by several factors including nutrient restricted, length of restriction, and severity of restriction in addition to type of diet fed following restriction (high or low energy, genetics of the animal, and environment. Therefore, relying on compensatory growth may not always yield satisfactory results.

Grazing Management

The principles of grazing management are centered on the temporal and spatial distribution of various kinds and number of livestock (Heitschmidt, 1988). Particular management strategies affect forage quantity and nutritive value, along with individual

animal performance and animal production per unit of land. Several management factors play a role in an overall grazing structure: intensity, method, and timing of grazing (Sollenberger et al., 2012). This review will focus on the effects of grazing intensity and stocking method.

Grazing Intensity

Stocking rate is the most common animal-based measure of grazing intensity (Sollenberger et al., 2012). Several researchers have reported that intensity of grazing is the single most influential factor in a grazing system (Jones and Jones, 1997; Lomas et al., 2000; Sollenberger and Newman, 2007). Hart and Ashby (1998) summarized 55 years of grazing evaluating the effects of differing grazing intensities on forage mass and animal performance. From 1939 to 1994, shortgrass rangeland consisting primarily of blue grama were stocked at a mean of either 16.7, 23.0, or 36.5 animal days per hectare which removed approximately 20, 40, and 60% of the average annual net production (**AANP**) of the forage. The authors reported that as grazing intensity increased, forage mass decreased as well as individual animal gain. However, the moderate stocking rate proved to be the most profitable as well as sustainable. Similar to Hart and Ashby (1998), Biondini et al. (1998) also reported that over an 8-year period evaluating differing grazing intensities on mixed shortgrass prairie in North Dakota, that grazing pressures which removed 50% of the AANP were sustainable and resulted in desired maintenance of range condition. Biondini et al. (1998) also reported that when 90% of the AANP was removed there was a significant decline in standing biomass and biomass-N signifying

that sustained high intensity grazing could possibly lead to long term negative effects on range condition.

Bates et al. (1996) evaluated the effects of three grazing intensities on forage persistence and animal performance in continuously stocked alfalfa pastures over 3 years. Each year, yearling steers grazed alfalfa at differing levels of forage allowance per animal, either 503, 987, or 1828 kg/500 kg of BW. Forage allowance was manipulated through differing stocking rates. As forage allowance increased, so did plant persistence. At the conclusion of the 3-year study, the highest level of forage allowance had 30% more plants remaining than the low and medium levels. Additionally, as forage allowance decreased, bermudagrass encroachment into the alfalfa stand increased. At the conclusion of the trial, bermudagrass averaged 56, 42, and 21% of the groundcover for the low, medium, and high forage allowance treatments, respectively. As forage allowance increased, individual animal performance increased as well. However during the 2^{nd} and 3^{rd} year of the trial, the low forage allowance treatment had increased gain per hectare due to increased stocking rate. There were no differences reported in forage nutritive value as a result of grazing intensity, therefore performance differences would mainly be a result of differences in forage intake. Of note, even though the highest grazing intensity resulted in the greatest gain per hectare, the persistence of the alfalfa stand was negatively impacted as intensity increased, therefore the highest level of gain per hectare was likely not sustainable over time. The authors concluded that the medium level of forage allowance was the best balance between stand persistence and animal performance, both on an individual basis and BW gain per unit of land.

Ackerman et al. (2001) and Beck et al. (2016) also reported increases in animal production per hectare as grazing intensity increased. Ackerman et al. (2001) reported that gain/ha linearly increased and ADG linearly decreased as stocking rate increased from 392 kg of BW/ha to 560 kg of BW/ha to 840 kg of BW/ha for steers grazing Old World bluestem. Beck et al. (2016) reported that calf BW weaned was greater for bermudagrass pastures interseeded with cool-season annuals stocked to provide 0.4 ha/cow-calf pair (543 kg BW/ha) than those stocked to provide 0.8 ha/cow-calf pair (281 kg BW/ha).

Uniform decreases in ADG as grazing intensity increases have not been universally reported. Bryan and Prigge (1994) evaluated the effect of 3 stocking rates (3, 4, or 5 steers/ha) on steer performance, animal production per hectare, and nutritive value of Kentucky bluegrass-white clover mixtures. Steers stocked at 4 steers/ha had the highest ADG (0.81 kg/d), which was greater than both the 3 steers/ha (0.73 kg/d) and 5 steers/ha treatment (0.62 kg/d). Likewise, animal production per hectare was also greatest for pastures stocked with 4 steers/ha though pastures stocked at 5 steers/ha was similar. Body weight gain per hectare for pastures stocked at 4 steers/ha was almost 50% greater than pastures stocked at 3 steers/ha (292 and 201 kg/ha). Similar to Beck et al. (2016), Bryan and Prigge (1994) reported increases in forage nutritive value with increased stocking rate. The authors reported a linear increase in CP and linear decreases in neutral detergent fiber (**NDF**), and acid detergent fiber (**ADF**) as stocking rate increased. The increase in ADG from 3 to 4 steers/ha is likely due to increased forage nutritive value

with minimal differences in intake. When increasing stocking rate from 4 to 5 steers/ha, it is likely that intake was limited during parts of the grazing season.

There is conflicting research regarding the effect that increased grazing intensity has on forage nutritive value though in general as intensity increases, nutritive value either increases (Bryan and Prigge, 1994; Schlegel et al., 2000; Beck et al., 2016) or is equal (Bates et al., 1996; Ackerman et al., 2001; Arthington et al., 2007). Increased forage nutritive value as a result of increased grazing intensity is attributable to increased leaf area as a proportion of total plant size and decreased plant age as a result of decreased time between animal visits (Sollenberger et al., 2012). However, as discussed previously, there is usually an associated decrease in ADG as intensity increases, leading to a negative correlation between forage nutritive value and ADG in many experiments. Therefore, the increase in forage nutritive value observed in some studies is not enough to overcome the decrease in forage quantity available to the animal (Hernandez Garay et al., 2004).

These studies would indicate that as grazing intensity increases, ADG decreases, however, in general gain per hectare increases due to increased stocking rate. Additionally, it would seem that the major factor influencing animal gain is the amount of available forage, not nutritive value, which in turns influences forage intake. The differences in forage intake across differing grazing intensities can be a result of both decreased quantity of forage over time due to increased grazing intensity (Hart and Ashby, 1998; Biondini et al., 1998) and decreased forage allowance as a result of stocking rate (Mott and Moore, 1985; Bates et al., 1996). Grazing intensity is the most

important grazing management decision because of its major effect on forage persistence and productivity along with its effects on animal performance (Sollenberger et al., 2012).

Stocking Method

Much research has been conducted to determine the effect of grazing, or stocking, method on pasture conditions and animal performance. Allen et al. (2011) defined stocking method as a defined procedure or technique to manipulate animals in space and time to achieve a specific objective. For the purposes of this review we will focus on research comparing continuous and rotational grazing.

Rotational grazing in the current widespread form was put forth by Savory and Parsons (1980) in which short periods of grazing are followed by longer periods of rest. This is to ensure that the plant has time to regrow after being bitten, before being bitten for a second time. The goal of rotational stocking methods was to increase animal production by ensuring key plant species had adequate growth and enabling livestock to efficiently harvest forage (Briske et al., 2008). Rotational grazing was purported to do this by improving species composition, reducing patch grazing by increasing stock density, and ensuring more uniform distribution of animals over pasture. However, in practice, research evaluating the effect of continuous and rotational grazing on forage quantity, nutritive value, and animal performance is conflicting.

The most common way of measuring forage quantity is indirectly through stocking rate (Sollenberger et al., 2012). Aiken (1998) reported that bermudagrass sod-seeded with wheat-ryegrass pastures rotationally grazed by yearling steers had 34%

greater average stocking rate compared to continuously grazed pastures. Similar increases in average stocking rate have also been reported by Bertelsen et al. (1993), Volesky et al. (1994), and Hoveland et al. (1997). Greater measures of forage quantity proxies may be due to increased efficiency of forage utilization. Due to more uniform spacing of animals in rotationally grazed pastures, pastures are grazed more homogenously than under continuous grazing. Teague and Downhower (2003) reported that patch grazing in larger pastures leads to overstocking on small areas within the pasture and insufficient stocking in other areas leading to deterioration of the overgrazed sections.

Effects of stocking method on forage nutritive value are conflicting. Sollenberger and Newman (2007) reported that if forage quantity is not limiting, nutritive value of continuously grazed pastures may be greater. This is due to increased opportunity for selection. However, under more intensive grazing, forage nutritive value may be greater in rotationally grazed pastures due to the forage being grazed more uniformly, resulting in less mature regrowth throughout the pasture. Timing of forage sampling can also have an effect on forage nutritive value relative to treatments. Bertelsen et al. (1993) reported measured diet sample quality of alfalfa-tall fescue-orchardgrass pastures under continuous or rotational grazing pre- and post-graze at differing time points throughout the grazing season. The authors reported that pre-graze diet samples from continuously grazed pastures had greater NDF and ADF, and decreased CP compared to rotationally grazed pastures. However, the post-graze diet samples from the continuously grazed pastures had lower levels of ADF and NDF, and increased CP compared to rotationally grazed pastures, likely due to increased selection for animals on continuously grazed

pastures. Therefore, timing of sampling can influence any inferences made about the effects of stocking method on forage nutritive value. Additionally, the authors reported that time of year plays a greater role in forage nutritive value than stocking method. Sollenberger et al. (2012) concluded that due to variation in how forage nutritive value is measured across experiments makes overall conclusions difficult. In these instances, animal performance should be used to assess impact of grazing system.

Similar individual ADG have been widely reported for continuous and rotationally grazed pastures regardless of whether stocking rates are equal between stocking methods (Hart et al., 1993; Lomas et al., 2000) or greater for rotationally grazed animals (Heitschmidt et al., 1982; Pitts and Bryant, 1987; Bertelsen et al., 1993; Hoveland et al., 1997). Jung et al. (1985) reported that ADG of heifers grazing smooth bromegrass were similar when continuous and rotationally grazed pastures were stocked at the same rate (2.9 animals/ha). Likewise, when rotationally grazed pastures were stocked at a higher rate (3.8 animlas/ha), ADG of heifers were similar between stocking methods. This lead to increased gain per hectare for the rotationally grazed pastures. However, Walton et al. (1981) reported both increased ADG and increased gain per hectare for rotationally grazed alfalfa-bromegrass-creeping red fescue pastures compared to continuously grazed pastures. Additionally, there have been experiments which reported increased ADG of calves continuously grazing compared to calves rotationally grazing. This was attributed to greater selection and therefore a diet of higher nutritive value (Volesky et al., 1990). In these instances, it is likely that an increase in stocking rate, thereby limiting selectivity would have yielded similar ADG between stocking

methods. Briske et al. (2008) and Sollenberger et al. (2012) both concluded that in general stocking method does not impact ADG of animals. Additionally, Briske et al. (2008) concluded that gain per hectare was also not likely impacted by stocking method. However, Sollenberger et al. (2012), in evaluating not only studies on rangeland but also on improved pastures, concluded that the likelihood of observing increased gain per hectare is greater for improved cool season forages. This is in support of the findings of Walton et al. (1981), Jung et al. (1985), and Bertelsen et al. (1993).

The potential impacts of stocking method are important in that they can possibly affect long term plant persistence and species composition of pastures. However, as previously discussed, the most important part of any grazing management plan is to determine appropriate grazing intensity, followed in importance by possibly implementing a more intensive stocking method. Impacts of stocking method are more likely to be observed in improved cool season forages rather than in rangeland settings.

Corn Residue Modification

Due to the increased price of grain, largely due to expansion of ethanol production during the past 10 years, it is estimated that 0.526 million ha of grazing land were converted to crop land in the Western Corn Belt from 2006 – 2011 (Wright and Wimberly, 2013). As a result of this conversion, there is a decreased supply of traditional grass forages available for use in beef production. Additionally, the amount of corn residue available for use has increased. Watson et al. (2015) reported that for every 1 kg of corn grain produced, there is 0.8 kg of residue produced. However, the nutritive value of corn residue varies between plant parts. Fernandez-Rivera and Klopfenstein (1989)

reported that NDF of the husk and leaf portion of the corn plant (85%) were similar to the stem (84.4%) and less than the cob (94.1%). Crude protein content of the three plant parts was 3.7, 3.0, and 2.6%, respectively. However, in vitro dry matter digestibility (IVDMD) for the husk and leaf was 51.6% compared to 42.6% for the stem and 33.6% for the cob. Additionally, Fernandez-Rivera and Klopfenstein (1989) reported proportions of each plant part as a percentage of the corn plant. Husk and leaf comprised 45.5% of the total, while stem and cob were 37.2 and 13.5% of the total, respectively. McGee et al. (2012) reported similar plant proportions as Fernandez-Rivera and Klopfenstein (1989) but separated the husk and leaf into separate components. Similar to Fernandez-Rivera and Klopfenstein (1989), McGee et al. (2012) reported that the husk and leaf portion of the corn plant had the greatest IVDMD. The stem and cob fractions of the plant only had IVDMD values of 34 and 41%, respectively. Therefore, depending on what plant parts are consumed by the animal, cattle consuming corn residue can have a highly variable diet in terms of nutritive value. Furthermore, regardless of variation between the nutritive value of the plant parts, corn residue is generally regarded as a low-quality forage. Therefore, possible methods to improve the nutritive value of the residue may then be beneficial.

Chemical Treatment

As previously stated, corn residue is generally regarded as a low-quality forage because the residue is only available after the plant has reached maturity, resulting in lowered protein and digestibility values compared to the plant at a less mature state (Klopfenstein, 1987). One method of improving the digestibility of corn residue is

through the use of chemical treatment. Klopfenstein (1978), reported that alkaline treatment of residue serves to increase both the rate and extent of digestion of cellulose and hemicellulose, likely due to the breaking of bonds between the lignin and cellulose or hemicellulose. By breaking the bonds between lignin and cellulose and hemicellulose, rumen microbes have greater access and increase degradation. Klopfenstein et al. (1972) reported that by treating poor quality roughages such as corn residue with 5% NaOH increased in vivo organic matter digestibility of corn residue from 40.9 to 60.3%. Fahey et al. (1993) summarized the results of 24 studies evaluating the effect of NaOH on low quality forages. Fahey et al. (1993) reported that DMI of residues was increased by 22% and IVDMD was increased by 30%. However, due to safety concerns related to the use of NaOH, application has been limited (Watson et al., 2015).

Recently, CaO has been shown to be safer, while still remaining effective (Watson et al., 2015). Shreck et al. (2015a) evaluated the effect of replacing 20% of corn with corn residue treated with 5% CaO when included in a finishing diet containing 40% wet distillers grains plus solubles (WDGS) on performance of yearling steers. Steers consuming diets with CaO treated corn residue had similar final BW, ADG, DMI, and G:F as steers consuming the control diet which only contained 3.33% corn residue. Steers consuming treated residue had increased ADG (1.74 kg/d) compared to steers consuming diets with 20% untreated corn residue (1.59 kg/d). CaO treated residue also lead to a 5% increase in feed efficiency and 26 kg heavier final BW. Shreck et al. (2015a) also evaluated the effect of treating corn residue with CaO on diet digestibility utilizing similar diets to the finishing trial with the exception that corn residue was increased to

25% of the diet. CaO treatment of residue led to an increase in apparent total tract OM digestibility (78.4%) compared to diets containing untreated residue at 25% (66.3%) and no difference in control diets (72.1%). Neutral detergent fiber digestibility was increased for the treated residue diets compared to both the control and untreated residue diets which were similar to one another. This illustrates the effect that CaO treatment has on the digestibility of the cell wall component of corn residue.

Similarly, Chapple et al. (2015) reported that when CaO treated corn residue replaced 20% of corn in a finishing diet containing 40% MDGS, steer ADG was similar to a control diet containing 5% untreated corn stover. Conversely, Duckworth et al. (2014) reported that steers consuming finishing diets containing 20% CaO treated corn residue had decreased ADG compared to steers consuming the same diet with untreated corn residue. However, Duckworth et al. (2014) ground the untreated corn stover through a 2.5-cm screen and applied water to bring the moisture level to 50% and ensiled whereas the untreated residue fed by Shreck et al. (2015a) and Chapple et al. (2015) was ground to a larger size (7.6 cm) and not ensiled. Therefore, the ensiling process utilized by Duckworth et al. (2014) negated any benefit to CaO treatment. This may imply that the ensiling, rather than the CaO treatment, had a greater effect on residue quality.

Treated corn residue can also improve performance of growing cattle. Peterson et al. (2015) fed corn residue treated with 5% CaO to growing steer calves. Diets contained 70% corn residue and 30% WDGS. Steers consuming diets containing CaO treated corn residue had greater intakes (0.5 kg/d) and gained 0.07 kg/d more than steers consuming untreated residue, however, unlike results from finishing studies, feed efficiency did not

differ. Given the small improvement in performance due to alkaline treatment, treating corn residue to be fed in growing diets may not be economically beneficial.

Treating corn residue with 5% CaO can improve the digestibility of corn residue. Additionally, CaO treated corn residue can be included up to 20% of the total finishing diet when MDGS or WDGS are present in the diet at 40% with no decrease in performance. During times of high grain prices, the use of alkaline treated corn residue may provide an opportunity to decrease diet costs. However, response to alkaline treatment is lower in growing diets and may not be beneficial.

Physical Treatment

In addition to chemical treatment, feeding value of corn residue can be enhanced through physical treatment as well. The two most common methods are through grinding and pelleting (Fahey et al., 1993). Grinding decreases the particle size, increases surface area, and increases bulk density of the residue (Laredo and Minson, 1975). By decreasing particle size and increasing bulk density, rate of passage of the residue can be increased thereby increasing DMI (Minson, 1990). Shain et al. (1996) evaluated the effect of grind size of alfalfa and wheat straw in finishing diets. Cattle were fed diets containing alfalfa or wheat straw ground to either 0.95, 7.62, or 12.7 cm. Alfalfa and wheat straw were included in the diet to provide equal amounts of NDF, therefore alfalfa was fed at 10% of the total diet while wheat straw was included at 5.2%. For both roughages, when ground to 0.95 cm, ADG increased and feed efficiency increased compared to 12.7 cm. Osbourn et al. (1976) reported that intake of forages generally increased as particle size decreased up until particle size was less than 1 mm. Additionally, Shreck et al. (2015b) reported that

decreasing grind size also increased response of corn residue to CaO treatment. However, storage of finely ground forages can be difficult, with high levels of shrink and dust. By pelleting ground residue, which increases bulk density even further, ease of handling and storage can be increased.

In general, pelleting of feed has been reported to increase DMI (Campling and Freer, 1966; Coleman et al., 1978; Peterson et al., 2015). Peterson et al. (2015) reported that pelleting corn residue increased DMI 25.1% when included in a growing diet at 60% of the diet DM with the remaining diet comprised of distillers grains and supplement compared to unpelleted residue included at the same level. Pelleting also increased ADG by 9.1% from 1.31 to 1.43 kg/d. Feed efficiency was decreased by 11% when residue was pelleted. Decreases in digestibility have been reported by other as well (Campling and Freer, 1966; Greenhalgh and Reid, 1973). The decrease in digestibility is likely due to the increased passage rate previously discussed with reduction of particle size. However, decreases in digestibility are offset by increases in DMI.

As previously discussed, alkaline treatment of corn residue increases digestibility of the residue. Therefore, by alkaline treating corn residue prior to pelleting, decreases in digestibility can possibly be offset. Peterson et al. (2015) evaluated the effects of feeding a complete pelleted feed containing CaO treated corn residue and DDGS compared to an unpelleted control. Pelleting and alkaline treatment increased ending BW, ADG, and DMI. However, feed efficiency was still lower compared to the control.

Modification of corn residue through chemical treatment can increase digestibility of the plant parts and reduction of particle size through physical means can increase DMI

and ADG with small decreases in digestibility. Research has proven that treated corn residue can effectively replace up to 20% of corn in finishing diets with no decreases in performance. However, alkaline treatment of forage when fed to growing cattle has led to relatively small gains in performance that are currently not economically beneficial. However, alkaline treatment combined with pelleting can increase performance over just utilizing chemical or physical treatments by themselves in growing diets. Additionally, novel processes have been developed to combine alkaline treated corn residue with DDGS in a pelleted form that can be easily handled and stored. This pellet could be of use in supplementing grazing animals, by providing supplemental energy and protein and decreasing forage intake thereby increasing stocking rate on pastures that are less available and more expensive than in previous decades.

Conclusion

The research discussed in this literature review clearly shows that supplementation of grazing cattle can increase performance and stocking rate through a forage substitution effect. However, profitability of supplementation is influenced by period of ownership and timing of supplementation relative to finishing due to possible exhibitions of compensatory gain. Additionally, grazing management employed to maximize performance of animals and production per unit of land is likely influenced more by decisions made relative to level of grazing intensity rather than stocking method, however, in cool season improved forages stocking method can also influence outcomes.

Corn residue is likely to remain a relatively inexpensive and abundant source of forage and grazing resources in Nebraska. Through chemical and physical treatment, utilization of the residue can be improved. The objectives of this research were to:

1. Evaluate the effects of summer supplementation of calves grazing smooth bromegrass during the summer, following supplementation in the winter while grazing corn residue, on the summer performance of yearling steers, along with subsequent finishing performance and carcass characteristics. Additionally, the feasibility of backgrounding yearling steers in pens during the summer, rather than on pasture, was evaluated along with the economics associated with each management strategy.
2. Evaluate the effects of differing levels of grazing intensity and continuously or rotationally grazing smooth bromegrass during the summer on yearling steer performance and land production per hectare.
3. Evaluate the effects on performance of calves when supplemented with differing rates of a pellet containing CaO treated corn residue and byproducts while consuming basal forage diets of differing qualities.

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CHAPTER II

Performance and economics of supplementing yearlings on smooth bromegrass pastures.[1]

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ABSTRACT

Performance of implanted steers grazing smooth bromegrass was evaluated over 5 consecutive years from 2010-2014. Treatments consisted of cattle grazing bromegrass pastures fertilized with 90 kg N/ha (FERT), unfertilized pastures stocked with cattle that received distillers grains plus solubles (DGS) at 0.6% of BW (SUPP), and unfertilized pastures stocked with cattle that received no supplement (CON). Cattle supplemented with DGS had greater ADG (1.19 kg/d; $P < 0.01$) than CON and FERT treatments (0.83 and 0.86 kg/d, respectively) which did not differ ($P = 0.44$). Put and take animals were used to maintain similar grazing intensity across treatments and led to variable stocking rates. Stocking rates for SUPP (10.95 AUM/ha) and FERT (10.73 AUM/ha) cattle were similar to one another ($P = 0.75$) and both were greater than CON (6.72 AUM/ha) cattle ($P < 0.01$). Additionally, profitability of treatments was evaluated in an economic analysis utilizing 10 years of data in which the same treatments were applied from 2005-2014. Net returns were greatest for SUPP ($69.32) cattle followed by FERT ($50.92) and then CON ($30.68) cattle ($P < 0.01$). In the current analysis, SUPP was the most profitable treatment in 7 of the 10 years, with FERT being the most profitable in the other 3 years. In no year was CON more profitable than SUPP or FERT. Fluctuating market conditions and changes of input costs affect the overall profitability of all 3 treatments and in relation to one another. In this scenario, holding all prices constant except DGS, price of DGS would have to increase by 19 and 40% ($42.45 and $89.20/908 kg) in order for FERT and CON to be more profitable than SUPP, respectively.

Key words: supplementation, bromegrass, distillers grains, fertilization, economics

INTRODUCTION

Protein is commonly the first limiting nutrient in forage based diets. Supplementing growing calves grazing cool season grasses with a rumen undegradeable protein (RUP) source increases gain (Anderson et al., 1988) by meeting calves metabolizable protein (MP) requirement. Cool season grasses often supply an adequate amount of rumen degradeable protein (RDP) to the grazing animal, but are often deficient in RUP (Klopfenstein, 1996; Buckner et al., 2013). Supplementing grazing animals with an energy source, once MP requirements are met, can also illicit a gain response (Horn et al., 1995). However, supplementation may not lead to any biological response if the first limiting nutrient is not met.

Energy supplementation to cattle consuming higher-quality forages can often lead to decreases in forage intake. In an analysis of 66 studies, Moore et al. (1999) reported that when forage TDN:CP ratio is less than 7:1 (signifying sufficient CP) or when voluntary forage intake was greater than 1.75% of BW without supplementation, supplementation decreased forage intake. This substitution effect then allows for increased stocking rates. Distillers grains plus solubles (DGS) provide both protein and energy. In a summary of 8 trials supplementing DGS to grazing cattle, ADG was increased by 0.24 and 0.40 kg/d when DGS was supplemented at 1.82 and 3.41 kg daily, respectively (Klopfenstein et al., 2007). Additionally, each 0.45 kg of DGS fed decreased forage intake by 0.23 kg. Feeding excess protein can serve as a fertilizer once the amino acids are deaminated and the N is excreted in the form of urea onto the pasture.

Adding N fertilizer to smooth bromegrass pastures increases forage production, but does not impact forage quality (Watson et al., 2012). Therefore, N fertilization can increase stocking rates. Though supplementation and N fertilization may increase performance responses and stocking rate, profitability of the grazing system may not be improved due to cost. Profitability of these management strategies can vary from year to year with changing input costs. Therefore, in order to properly assess the most profitable management strategy for yearling cattle grazing smooth bromegrass, net returns, relative to treatments must be evaluated as well.

The objective of this study was to summarize 5 years of cattle performance data and evaluate the effects of DGS supplementation or N fertilization on cattle backgrounding economics over a 10-year period.

MATERIALS AND METHODS

Four hundred and fifty yearling steers grazed smooth bromegrass pastures over the course of 10 grazing seasons, from 2005-2014, at the Eastern Nebraska Research and Extension Center near Mead, NE. Performance results from 2005-2009 have been previously reported by Greenquist et al. (2009) and Watson et al. (2012). During the first 5 years of the study, from 2005-2009, cattle did not receive an implant, whereas from 2010-2014 all cattle received an implant containing 40 mg trenbalone acetate and 8 mg estradiol (Revalor-G; Merck Animal Health, Summit, NJ). All animals involved in this study were managed in accordance with the protocols approved by the Animal Care and Use Committee at the University of Nebraska.

Three treatments were applied over the 10-year period consisting of cattle grazing bromegrass pastures fertilized with 90 kg N/ha (FERT), unfertilized pastures stocked with cattle that received distillers grains plus solubles (DGS) at 0.6% of BW (SUPP), and unfertilized pastures stocked with cattle that received no supplement (CON).

Pasture and Animal Management

Each year, 45 crossbred steer calves (318 kg, SD = 9.7) were assigned to 1 of 3 treatments with 3 replications per treatment. Prior to the start of the 10 years, treatments were allocated randomly to 1 of 3 pasture areas within each of 3 blocks in a randomized complete block design. Treatments were then maintained on the same pasture areas for the remainder of the 10 years. Each pasture area within each block was divided into 6 paddocks that were separated by a single strand of electric fence and consisted of 0.33 ha/paddock for the FERT and SUPP treatments and 0.48 ha/paddock for the CON treatment. Paddocks were rotationally grazed for an average of 152 days per year from April to September. The grazing period was divided into 5 cycles with cycle 1 lasting 24 days and cycles 2, 3, and 4 lasting 36 days. Cycle 5 lasted between 24 and 36 days depending on available forage. Cattle rotated paddocks every 4 d during cycle 1 and 6 d during cycles 2, 3, and 4. Time spent in each paddock during cycle 5 was between 4 and 6 d depending on available forage. For the FERT pastures, urea was surface applied as the N source at a rate of 90 kg N/ha in late March or early April, prior to the initiation of grazing.

Five tester animals were maintained on each pasture at all times for performance measurements. A variable stocking rate was used in order to maintain a similar grazing

pressure across all 3 treatments by utilizing put and take animals that were added or removed depending on forage production. Determination of forage yield was conducted visually to maintain approximately 10 cm of standing forage at the conclusion of grazing. By utilizing put and take animals and varying stocking rate, the effects of treatment on animal performance and animal production per hectare of land were measured while maintaining similar grazing pressure across treatments. Put and take animals were not used to calculate individual performance but were used to calculate total number of head days. Number of head days for each treatment was calculated by multiplying the number of test steers by number of grazing days plus number of put and take animals multiplied by number of grazing days on each pasture. Pastures were initially stocked each spring at a rate of 6.82 animal unit months (AUM)/ha for CON cattle while the FERT and SUPP pastures were stocked at a rate of 9.88 AUM/ha. To calculate AUM/ha, total head days for each pasture was converted to total months, multiplied by average BW of the tester animals, expressed as animal units (454 kg), and then divided by the pasture area (ha).

Beginning and ending BW measurements were collected on 3 consecutive days and averaged following 5 days of being limit fed a diet of 50% alfalfa hay and 50% Sweet Bran at approximately 2% of BW to equalize gut fill (Watson et al., 2013). In order to update supplement amount for the SUPP cattle, BW of all cattle were measured in the morning at the beginning of each cycle and shrunk 4% to account for gut fill.

Economic Analysis

Data from all 10 years were combined to conduct the economic analysis, the first five years reported by Watson et al. (2012) and the subsequent 5 years in which steers

were implanted. For the economic analysis, all prices are based on a 5-year average from 2012-2016 to reflect the recent variability in market prices of inputs. Total costs for each system included initial animal cost, yardage, pasture rent, N fertilizer, health and processing, death loss, interest, and supplement cost (Table 1). Interest rates reported by the Federal Reserve Bank of Kansas City for agricultural operating loans over the 5-year period averaged 5.4%. Interest was applied to half of the initial animal cost and the total of all other costs for the length of ownership. Grazing yardage was included at $0.10/animal daily for the CON and FERT treatments to account for fence maintenance, checking on animals, and watering. Yardage was increased to $0.20/animal daily for the SUPP treatment to account for extra labor incurred due to daily supplementation. Pasture rent was charged at a rate of $379.39/ha (Jansen and Wilson, 2016). As stocking rate varied between treatments, cost per AUM also changed. For CON cattle cost was $55.63/AUM for the grazing period while for FERT and SUPP cattle cost was $38.40/AUM. Fertilizer costs for urea were based off an average April price of $329.67/908 kg across years (USDA-NASS, 2017; DTN, 2017). Additionally, an application fee of $16.56/ha ($6.70/acre) was included. Dried distillers grains price used was $223.05/908 kg DM and was based off the average April price in Nebraska (USDA-AMS, 2017). A $25/908 kg delivery fee and 5% shrink were also applied to supplementation costs. For the summer grazing period, an $8.40/animal health and processing fee and a 0.5% death loss were charged for all treatments. Initial calf price ($178.86/45.4 kg) was based on Nebraska sale barn average for 320 to 340 kg steers in April from 2012-2016. Price received for calves at the end of the grazing season was

based on Nebraska sale barn average in September for 430 to 455 kg steers ($161.22/45.4 kg), which correlated to the ending BW of the CON and FERT treatments. To account for the 50 kg greater ending BW of SUPP steers, a $6.88/45.4 kg price slide was used. This was calculated as the average difference between 430 to 455 kg and 475 to 500 kg steer price in September. Therefore, ending calf price for SUPP steers was $154.34/45.4 kg.

Profitability was calculated as live animal revenue at the conclusion of the grazing season minus total costs. Cost of gain (COG) was also calculated by dividing the total costs incurred, excluding initial steer price, by total weight gained during the grazing season. Breakeven prices were calculated for each treatment by dividing total costs by BW at the end of the grazing period.

Sensitivity analyses were conducted for all three treatments evaluating the effect of changing land rental ($/0.4 ha) and steer purchase price ($/45.4 kg) while holding all other costs constant. Additional analyses were conducted for the FERT treatment evaluating effect of changing land rental ($/0.4 ha) and fertilizer price ($/908 kg) and for the SUPP treatment comparing prices of land rental ($/0.4 ha) and dried distillers grains prices ($/908 kg).

Statistical Analysis

Statistical analysis was performed using the GLIMMIX procedure of SAS (SAS Institute Inc., Cary, NC). Year was considered a random effect and pasture within block was the experimental unit. The model tested for effects of block, year, treatment, and year × treatment interactions for each response variable. Total precipitation from March-September in each year was tested as a covariate but was not significant and was

subsequently removed from the model ($P > 0.40$). The inclusion of year as a random effect likely accounted for the majority of the variation that could be explained by differences in precipitation across years. Differences were considered significant at $P < 0.05$. Tendencies are discussed at $P < 0.10$.

RESULTS AND DISCUSSION

Cattle Performance

Initial BW did not differ among treatments ($P = 0.39$; Table 2). There were no year × treatment interactions observed for measures of cattle performance ($P \geq 0.15$). Daily gain was greatest for SUPP steers (1.19 kg/d; $P < 0.01$) and similar for FERT and CON steers (0.86 and 0.83 kg/d, respectively; $P = 0.44$). This increase in gain led to greater ending BW for SUPP steers (490 kg) compared to FERT and CON steers (442 and 439 kg, respectively; $P < 0.01$). Increased summer gain with DGS supplementation at 0.6% of BW has been reported by Gillespie-Lewis et al. (2016) in heifers and Rolfe (2011) in steers. In these studies, in which animals were grazing summer range in the Nebraska Sandhills, summer gains were increased by 0.21 and 0.30 kg/d, respectively. Additionally, in a meta-analysis consisting of 13 pasture studies by Griffin et al. (2012), DGS supplemented at 0.6% of BW resulted in an increase of 0.26 kg/d compared to non-supplemented cattle. The greater increase in ADG in the current study of 0.34 kg/d is likely due in part to the greater forage quality of smooth bromegrass compared to Sandhills range which is comprised of primarily warm-season grasses (Volesky et al., 2005). Likewise, in the meta-analysis by Griffin et al. (2012) several of the studies utilized consisted of animals grazing warm season grasses. Watson et al. (2012) reported

an increase in ADG of 0.26 kg/d for steers supplemented with DGS at 0.6% of BW compared to non-supplemented steers during the initial 5-year period of the current study in which steers were not implanted. Lomas et al. (2009) reported a 0.14 kg/d increase in ADG for animals grazing smooth bromegrass when supplemented with ground grain sorghum at 0.5% of BW compared to no supplemental energy. Additionally, ADG for the non-supplemented steers (0.74 kg/d) in Lomas et al. (2009) was similar to the ADG for non-supplemented steers (0.68 kg/d) in Watson et al. (2012) and Griffin et al. (2012). Therefore, the increased ADG in the current study is likely due to a combination of the use of implants and providing a supplemental source of both protein and energy.

While CON treatment pastures were initially stocked at 69% (6.82 AUM/ha) the rate of FERT and SUPP cattle each year (9.88 AUM/ha), actual stocking rates varied within and across years due to put and take animals and averaged 6.72, 10.73, and 10.95 AUM/ha for the CON, FERT, and SUPP treatments, respectively (Figure 1). Therefore, CON pastures were stocked at an average of 63 and 61% of FERT and SUPP pastures, respectively, over the 5-year period. These stocking rates, relative to one another, are similar to actual stocking rates reported by Watson et al. (2012) in which CON pastures were stocked at 66% of FERT and 64% of SUPP pastures. Total AUM/ha, however, were greater for the 5 yr period (2005-2009) reported by Watson et al. (2012) compared to the current 5 yr period (2010-2014). This is likely due in part to drought in 2012 and management of pastures in 2013 to account for drought recovery. Increased stocking rate associated with FERT pastures is due to an increase in forage production, while not affecting forage quality (Watson et al., 2012). Forage production of control pastures was

reported to be 70% of the fertilized pastures which when combined with the initial 69% of fertilized stocking rate of control pastures led to similar weight gains between the two treatments. Therefore, without the greater amount of land provided to the control steers, ADG would have decreased. Decreased forage intake as a result of supplementation of energy has been widely documented (Cravey, 1993; Horn et al., 1995; MacDonald et al., 2007). Hales et al. (2007) reported up to a 3-fold increase in stocking rate with *ad libitum* soybean hulls intake (approximately 2.0% BW) for cattle grazing winter rye. In the current experiment, the increase in stocking rate due to supplementation was only 59.7%; however, supplementation was less than in Hales et al. (2007). Horn et al. (1995) reported an increase in stocking rate of 22 to 44% when cattle were supplemented at 0.65% of BW while grazing wheat pasture with either a high starch or high fiber energy supplement over a 3-yr period. Average daily gain response was only 0.15 kg/d greater for supplemented cattle compared to control cattle. The gain response reported by Horn et al. (1995) is similar to that of Lomas et al. (2009) which also supplied an energy supplement rather than a supplement that provided both energy and protein as in the current study. Stocking rate and gain responses as a result of supplementation vary across level and type of supplement, as well as basal forage quality.

Economic Analysis

Total costs differed for all treatments ($P < 0.01$) and were greatest for SUPP steers ($1568.64/steer) due to the increased cost of supplementation, followed by CON ($1519.92) and FERT steers ($1500.69; Table 3). In this analysis, the increased cost associated with land rental for CON ($71.17/steer) due to decreased stocking rates

compared to FERT, was greater than the additional cost of fertilizer ($54.57/steer) for the FERT treatment. Supplemented steers had the greatest total revenue per steer ($1637.96/steer; $P < 0.01$), while revenue for CON and FERT steers ($1550.59 and $1551.61, respectively) did not differ due to similar ADG and ending BW for those two treatments ($P = 0.87$). Over the grazing season, FERT and SUPP steers were both more profitable than CON steers, and SUPP steers were more profitable than FERT steers ($P < 0.01$). In this analysis, using prices from 2012-2016, all three treatments led to a positive net profit. Control steers had a net profit of $30.68/steer while FERT and SUPP steers had net profits of $50.92 and $69.32/steer, respectively. While SUPP steers had greater costs compared to CON and FERT steers, the increase in ADG due to supplementation with DGS led to greater ending BW and therefore greater revenue when sold. While FERT steers had similar revenue as CON steers, the difference in land rental costs and fertilization led to a greater net profit for FERT steers.

Cost of gain differed among all treatments ($P < 0.01$) and was greatest for CON steers ($0.96/kg) followed by FERT ($0.88/kg) and SUPP steers ($0.83/kg). Following the trend of COG, breakeven price per kg of ending BW was greatest for CON steers followed by FERT and then SUPP steers ($1.58, $1.56, and $1.48/kg, respectively; $P < 0.01$).

For every $5/45.4 kg increase in steer purchase price, profitability of CON cattle decreased by $35.86/steer (Table 4). Similarly, profitability for FERT and SUPP cattle decreased by $35.80 and $35.72/steer for the same increase in steer purchase price, respectively. As land rent increased by $10/0.4 ha, decreases in profitability per steer

were $13.90, $9.16, and $9.41 for CON, FERT, and SUPP, respectively. The greater decrease in profitability per unit increase in land rent for the CON compared to the FERT and SUPP cattle is attributable to the decreased stocking rate of that treatment. Although SUPP cattle have a numerically greater stocking rate than FERT, the decrease in profitability for the same unit change in land rent is actually $0.25 greater per steer. This is due to the FERT cattle having an average of 842 grazing head days per season while SUPP cattle had only 819. The numerically greater stocking rate for the SUPP cattle is then a product of the increased individual animal gain which makes up for the lesser amount of head days. Therefore, when only changing land rent price the SUPP cattle are impacted more than the FERT cattle.

Table 5 shows the effect of changing land rent and fertilizer price on the profitability per steer of FERT cattle. Increases in land rent are the same as those reported in Table 4. For every $50/908 kg increase in fertilizer price, profitability of FERT cattle decreased by $4.87/steer. When fertilizer price is held constant at $329.67/908 kg DM, FERT cattle were profitable at all land rent costs of $190/0.4 ha and below; whereas, at all land rent costs above $230/0.4 ha, FERT cattle had a negative profit per steer. As land rent increased by $10/0.4 ha, fertilizer price had to decrease by $96.25/908 kg in order to offset the increase in land rent.

When steer purchase price is held constant at $178.86/45.4 kg, CON cattle are not profitable when land rent is above $175/0.4 ha. However, as Table 5 indicates, FERT cattle are always profitable in this scenario for all fertilizer prices up to $600/908 kg. This illustrates the value of increased stocking rate due to fertilization. Holding all other inputs

constant, fertilizer price would have to increase by $208.10/908 kg to $706.50/908 kg in order for FERT and CON treatments to have equal profit per steer. Conversely, land price would need to decrease by $42.80/0.4 ha to $110.80/0.4 ha for both treatments to have the same profit per steer. In order for FERT profitability to be the same as SUPP cattle, fertilizer price would need to decrease by $189.20/908 kg to $308.60/908 kg.

Table 6 shows the effect of changing land rent and DGS price on the profitability per steer of SUPP cattle. Under these scenarios, SUPP cattle are profitable at all DGS prices as long as land rent is at or below $230/0.4 ha. Once land rent increased above $260/0.4 ha, SUPP cattle lost money regardless of DGS price. If land rent increased by $10/0.4 ha, DGS price would need to decrease by $21.61/908 kg in order for profit to remain the same. Land rent would have to decrease from $153.60/0.4 ha to $67.30/0.4 ha for CON to have equal profit to SUPP holding all other variables constant. Additionally, DGS price would have to increase to $312.25 and $265.50/908 kg in order to have equal profit per steer as CON and FERT, respectively.

IMPLICATIONS

Supplementing grazing cattle with DGS leads to increased animal gain and stocking rate per unit of land due to decreased forage intake and application of excess N onto pastures. Likewise, fertilization of pastures allows for a greater stocking rate compared to non-fertilized pasture; however, gains per steer do not differ between fertilized and control pastures. The profitability of each of these management strategies, relative to one another, is dependent on input costs associated with each treatment. Supplementation and fertilization lead to increased total costs, but in these scenarios also

led to increased revenue that offset the increased costs. With increasing land rent, especially in areas suitable for crop production, fertilization and supplementation provide opportunities for producers to more efficiently use available land.

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Table 1. Economic analysis input costs

Initial Steer Cost	$178.86/45.4 kg
Grazing Steer Value	$161.22/45.4 kg (439 kg base); $6.88/45.4 kg price slide
Grazing Yardage[1]	CON & FERT, $0.10/animal daily; SUPP, $0.20/animal daily
Health and processing	$8.40/animal
Death loss	0.50%
DDGS[2]	$223.05/908 kg DM plus $25/908 kg delivery fee and 5% shrink
Fertilizer	$329.67/908 kg urea plus $16.56/ha application fee
Land cash rent	$379.39/ha
Interest rate	5.4%

[1] Treatments consisted of nonfertilized paddocks (CON), paddocks fertilized with 90 kg N/ha (FERT), and nonfertilized paddocks grazed by steers supplemented with DGS at 0.6% of BW daily (SUPP).

[2] DDGS = dried distillers grains plus solubles

Table 2. Performance of yearling steers grazing smooth bromegrass pastures during the grazing season from 2010-2014

	Treatments[1]				
	CON	FERT	SUPP	SEM	*P* - Value
Initial BW, kg	318	317	318	9.69	0.39
Ending BW, kg	439[b]	442[b]	490[a]	6.97	< 0.01
ADG, kg/d	0.83[b]	0.86[b]	1.19[a]	0.05	< 0.01
Actual AUM/ha	6.72[b]	10.73[a]	10.95[a]	0.50	< 0.01

[a,b] From the *P*-values, means with differing superscripts are different ($P < 0.05$).

[1] Treatments consisted of nonfertilized paddocks (CON), paddocks fertilized with 90 kg N/ha (FERT), and nonfertilized paddocks grazed by steers supplemented with distillers grains at 0.6% of BW daily (SUPP).

Table 3. Profitability of yearling steers under differing summer management strategies

	Treatments[1]			SEM	P - Value
	CON	FERT	SUPP		
Total Costs, $[2]	1519.92^b	1500.69^c	1568.64^a	4.00	< 0.01
Total Revenue, $[2]	1550.59^b	1551.61^b	1637.96^a	6.76	< 0.01
Net Profit, $[2]	30.68^c	50.92^b	69.32^a	6.50	< 0.01
Breakeven, $[3]	1.58^a	1.56^b	1.48^c	0.01	< 0.01
COG, $[4]	0.96^a	0.88^b	0.83^c	0.02	< 0.01

^{a,b,c} Means within a row with differing superscripts are different (P < 0.05).

[1] Treatments consisted of nonfertilized paddocks (CON), paddocks fertilized with 90 kg N/ha (FERT), and nonfertilized paddocks grazed by steers supplemented with distillers grains at 0.6% of BW daily (SUPP).

[2] $/animal

[3] $/0.454 kg, ending BW

[4] Cost of gain, $/0.454 kg BW gained

Table 4. Effect of varying steer purchase and land rent price on profitability of yearling steers under differing summer management strategies[1]

Trt[2]	Land Rent, $/0.4 ha[3]	Steer Purchase Price, $/45.4 kg[3]						
		165	**170**	**175**	**180**	**185**	**190**	**195**
CON	100	204.53	168.67	132.82	96.96	61.11	25.25	(10.60)
	110	190.64	154.78	118.93	83.07	47.22	11.36	(24.49)
	120	176.74	140.89	105.03	69.18	33.32	(2.53)	(38.39)
	130	162.85	127.00	91.14	55.29	19.43	(16.42)	(52.28)
	140	148.96	113.10	77.25	41.39	5.54	(30.32)	(66.17)
	150	135.07	99.21	63.36	27.50	(8.35)	(44.21)	(80.06)
	160	121.18	85.32	49.46	13.61	(22.25)	(58.10)	(93.96)
	170	107.28	71.43	35.57	(0.28)	(36.14)	(71.99)	(107.85)
	180	93.39	57.54	21.68	(14.17)	(50.03)	(85.88)	(121.74)
	190	79.50	43.64	7.79	(28.07)	(63.92)	(99.78)	(135.63)
	200	65.61	29.75	(6.10)	(41.96)	(77.81)	(113.67)	(149.52)
		165	**170**	**175**	**180**	**185**	**190**	**195**
FERT	100	199.21	163.42	127.62	91.83	56.04	20.25	(15.54)
	110	190.05	154.26	118.47	82.68	46.89	11.09	(24.70)
	120	180.90	145.11	109.31	73.52	37.73	1.94	(33.85)
	130	171.74	135.95	100.16	64.37	28.58	(7.22)	(43.01)
	140	162.59	126.80	91.00	55.21	19.42	(16.37)	(52.16)
	150	153.43	117.64	81.85	46.06	10.27	(25.53)	(61.32)
	160	144.28	108.49	72.69	36.90	1.11	(34.68)	(70.47)
	170	135.12	99.33	63.54	27.75	(8.04)	(43.84)	(79.63)
	180	125.97	90.18	54.38	18.59	(17.20)	(52.99)	(88.78)
	190	116.81	81.02	45.23	9.44	(26.35)	(62.15)	(97.94)
	200	107.66	71.87	36.07	0.28	(35.51)	(71.30)	(107.09)
		165	**170**	**175**	**180**	**185**	**190**	**195**
SUPP	100	218.78	183.06	147.34	111.63	75.91	40.20	4.48
	110	209.36	173.65	137.93	102.22	66.50	30.78	(4.93)
	120	199.95	164.24	128.52	92.80	57.09	21.37	(14.34)
	130	190.54	154.82	119.11	83.39	47.68	11.96	(23.76)
	140	181.13	145.41	109.69	73.98	38.26	2.55	(33.17)
	150	171.71	136.00	100.28	64.57	28.85	(6.86)	(42.58)
	160	162.30	126.59	90.87	55.15	19.44	(16.28)	(51.99)
	170	152.89	117.17	81.46	45.74	10.03	(25.69)	(61.41)
	180	143.48	107.76	72.05	36.33	0.61	(35.10)	(70.82)
	190	134.07	98.35	62.63	26.92	(8.80)	(44.51)	(80.23)
	200	124.65	88.94	53.22	17.51	(18.21)	(53.93)	(89.64)

[1] Values without parentheses denote a positive net return, whereas values in parentheses denote a negative return.

[2] Treatments consisted of nonfertilized paddocks (CON), paddocks fertilized with 90 kg N/ha (FERT), and nonfertilized paddocks grazed by steers supplemented with distillers grains at 0.6% of BW daily (SUPP).
[3] 0.4 ha = 1 acre; 45.4 kg = 100 lb (cwt).

Table 5. Effect of varying fertilizer and land rent price on profitability of yearling steers grazing smooth bromegrass fertilized with 90 kg N/ha while holding other economic assumptions constant[1]

Land Rent, $/0.4 ha[2]	**Fertilizer price, $/908 kg[2]**							
	250	**300**	**350**	**400**	**450**	**500**	**550**	**600**
100	124.11	119.25	114.38	109.51	104.65	99.78	94.91	90.04
110	114.96	110.09	105.23	100.36	95.49	90.62	85.76	80.89
120	105.80	100.94	96.07	91.20	86.34	81.47	76.60	71.73
130	96.65	91.78	86.92	82.05	77.18	72.31	67.45	62.58
140	87.49	82.63	77.76	72.89	68.03	63.16	58.29	53.42
150	78.34	73.47	68.61	63.74	58.87	54.00	49.14	44.27
160	69.18	64.32	59.45	54.58	49.72	44.85	39.98	35.11
170	60.03	55.16	50.30	45.43	40.56	35.69	30.83	25.96
180	50.87	46.01	41.14	36.27	31.41	26.54	21.67	16.80
190	41.72	36.85	31.99	27.12	22.25	17.38	12.52	7.65
200	32.56	27.70	22.83	17.96	13.10	8.23	3.36	(1.51)
210	23.41	18.54	13.68	8.81	3.94	(0.93)	(5.79)	(10.66)
220	14.25	9.39	4.52	(0.35)	(5.21)	(10.08)	(14.95)	(19.82)
230	5.10	0.23	(4.63)	(9.50)	(14.37)	(19.24)	(24.10)	(28.97)
240	(4.06)	(8.92)	(13.79)	(18.66)	(23.52)	(28.39)	(33.26)	(38.13)

[1] Values without parentheses denote a positive net return, whereas values in parentheses denote a negative return. CON and SUPP treatments are not represented because no fertilizer was applied.

[2] 0.4 ha = 1 acre; 908 kg = 2000 lb (ton).

Table 6. Effect of varying dried distillers plus solubles (DDGS) and land rent price on profitability of yearling steers supplemented with DDGS while grazing smooth bromegrass while holding other economic assumptions constant[1]

Land Rent, $/0.4 ha[2]	**DDGS price, $/908 kg (DM)[2]**							
	180	**190**	**200**	**210**	**220**	**230**	**240**	**250**
100	152.63	148.51	144.39	140.28	136.16	132.04	127.92	123.80
110	143.22	139.10	134.98	130.86	126.75	122.63	118.51	114.39
120	133.81	129.69	125.57	121.45	117.33	113.22	109.10	104.98
130	124.40	120.28	116.16	112.04	107.92	103.80	99.68	95.57
140	114.98	110.86	106.75	102.63	98.51	94.39	90.27	86.15
150	105.57	101.45	97.33	93.22	89.10	84.98	80.86	76.74
160	96.16	92.04	87.92	83.80	79.69	75.57	71.45	67.33
170	86.75	82.63	78.51	74.39	70.27	66.15	62.04	57.92
180	77.33	73.22	69.10	64.98	60.86	56.74	52.62	48.51
190	67.92	63.80	59.69	55.57	51.45	47.33	43.21	39.09
200	58.51	54.39	50.27	46.16	42.04	37.92	33.80	29.68
210	49.10	44.98	40.86	36.74	32.62	28.51	24.39	20.27
220	39.69	35.57	31.45	27.33	23.21	19.09	14.98	10.86
230	30.27	26.16	22.04	17.92	13.80	9.68	5.56	1.45
240	20.86	16.74	12.63	8.51	4.39	0.27	(3.85)	(7.97)
250	11.45	7.33	3.21	(0.91)	(5.02)	(9.14)	(13.26)	(17.38)
260	2.04	(2.08)	(6.20)	(10.32)	(14.44)	(18.55)	(22.67)	(26.79)

[1] Values without parentheses denote a positive net return, whereas values in parentheses denote a negative return. CON and FERT treatments are not represented because no distillers grains were fed.

[2] 0.4 ha = 1 acre; 908 kg = 2000 lb (ton).

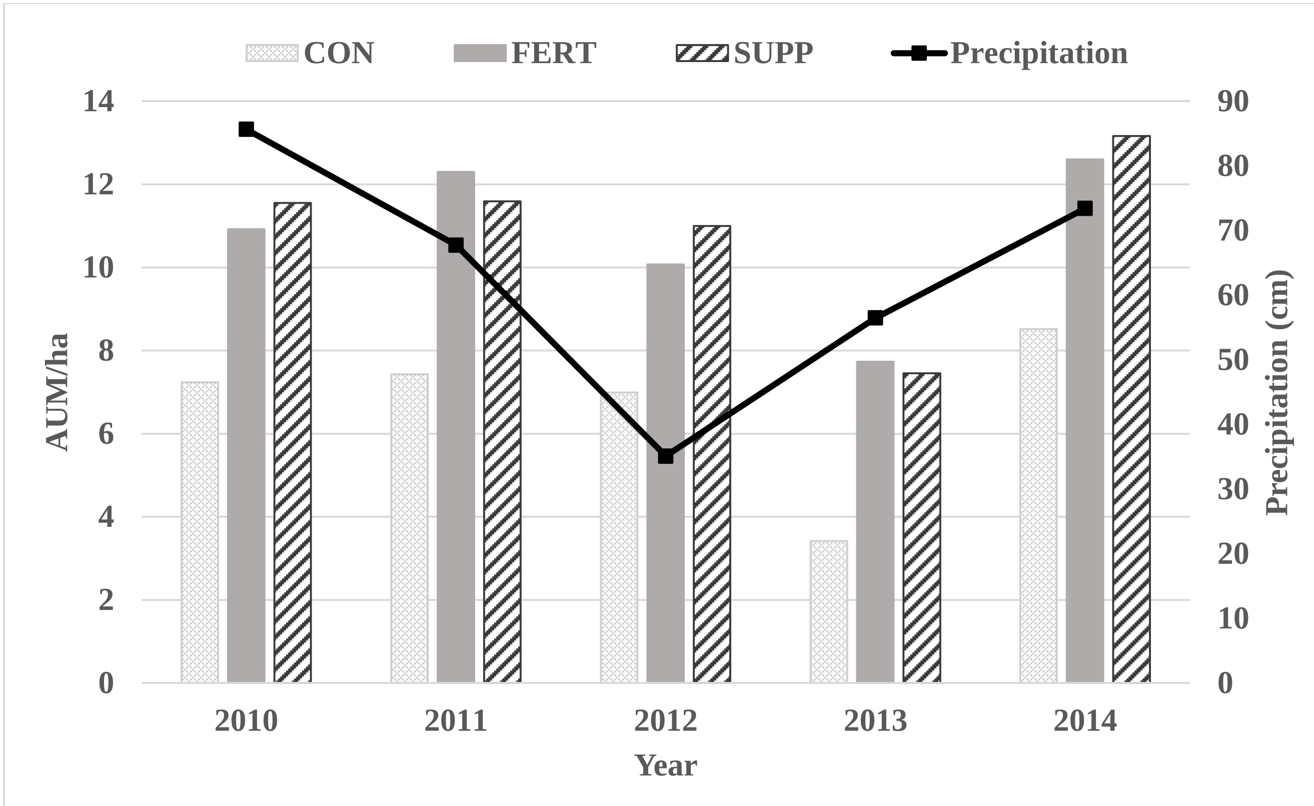

Figure 1. Average yearly stocking rate (AUM/ha) of yearling steers grazing smooth bromegrass pastures by treatment. Treatments consisted of nonfertilized paddocks (CON), paddocks fertilized with 90 kg N/ha (FERT), and nonfertilized paddocks grazed by steers supplemented with distillers grains at 0.6% of BW daily (SUPP). One AUM is equal to 308 kg of forage DM. Precipitation during the growing season (March through September) is also shown, following the right hand axis.

CHAPTER III

Effect of differing summer management strategies on performance, carcass characteristics, and profitability of yearling beef steers.[1]

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ABSTRACT

A 2-yr study was conducted to evaluate the effects of differing summer management strategies following winter supplementation on the finishing performance and economics of yearling beef steers. Each year, 240 crossbred steers (initial BW = 246 kg, SD = 13) were used in a randomized complete block design with 5 treatments. Steers were wintered on corn residue from November to mid-April and supplemented daily with MDGS at 1.0% of initial BW. After removal from stalks, steers were blocked by BW (n = 3), and stratified by BW within block using a 3-d average weight following 5 d of limit feeding at 2% of BW to equalize gut fill. Calves were then assigned to 1 of the 5 treatments with 4 replications per treatment each year. Treatments consisted of summer finished steers (**SHORT**), steers grazing smooth bromegrass and supplemented with DDGS at 0.6% of BW (**SUPP**), steers grazing smooth bromegrass with no supplement (**UNSUPP**), steers backgrounded in a pen to target ADG of 1.07 kg/d (**HI**), and backgrounded in pen to target ADG of 0.76 kg/d (**LO**). The level of targeted gain in the HI and LO treatments was equal to a 10-yr average of SUPP and UNSUPP gains on brome pastures. High and LO steers were fed a common backgrounding diet at 11.24 and 9.15% of initial metabolic BW, respectively. The summer grazing/backgrounding season lasted 156 d in year 1 and 161 d in year 2. Following the conclusion of the grazing season in September, SUPP, UNSUPP, HI, and LO steers summer treatment experimental units were preserved and fed a common finishing diet *ad libitum* until reaching 1.40 cm of 12th rib fat as assessed with ultrasound. There was a significant treatment × year interaction for performance variables and, therefore, data are reported by year. In year 1, summer

ADG differed among all backgrounding treatments ($P < 0.01$) with HI cattle having the greatest ADG (1.03 kg/d) followed by LO (0.81 kg/d), SUPP (0.73 kg/d), and UNSUPP (0.45 kg/d). In year 2, however, ADG was similar for HI and SUPP cattle (0.94 and 0.90 kg/d, respectively; $P > 0.23$) followed by LO cattle (0.75 kg/d) and then UNSUPP cattle (0.47 kg/d; $P < 0.01$). Feedlot ADG was greatest for SHORT cattle in year 1 with all backgrounded cattle having similar ADG during the finishing period, while in year 2, feedlot ADG was greatest for UNSUPP cattle ($P < 0.01$), suggesting compensatory gain, and was similar for all other treatments ($P > 0.26$). In year 1, UNSUPP cattle had the lowest HCW ($P < 0.01$) while in year 2 all summer backgrounded cattle had greater HCW than SHORT cattle, likely due to treatments being finished to a similar fat endpoint, compared to year 1. Overall, backgrounding programs increased HCW when all cattle were fed to a common fat endpoint. Profitability of treatments, especially for the SUPP and UNSUPP cattle, varied each year with differences in ADG and G:F. Therefore, programs designed to target compensatory gain in the feedlot may have limited success.

Key words: yearling steers, supplementation, distillers grains, backgrounding, economics

INTRODUCTION

Variations in grain prices over the last decade have caused subsequent fluctuations in the costs associated with finishing beef animals. During times of high grain prices, producers may choose to utilize a yearling system to decrease time spent finishing the animal, and therefore finishing costs per animal. Yearlings can be finished in the summer as short yearlings or in the fall and winter as long yearlings. In Nebraska,

the most common yearling system consists of grazing calves weaned in the fall grazing corn residue until spring, followed by grazing native or improved grass until early fall, at which point they then enter the feedlot to be finished. Additionally, utilization of a yearling system increases HCW relative to calf-feds (Adams et al., 2010). Previous research has evaluated optimal supplementation rates during both the winter and summer. Gillespie-Lewis et al. (2016) evaluated the effects of winter and subsequent summer supplementation in a yearling system and reported that greater amounts of supplementation while cattle graze corn residue is beneficial, but supplementation while grazing summer range was not, due to compensation of unsupplemented calves during the finishing period. Watson et al. (2012) reported increased gains for yearling steers grazing smooth bromegrass during the summer compared to unsupplemented steers. Effect of supplementation strategies on profitability of yearling steers grazing a cool-season grass in the summer following winter supplementation while grazing corn residue has not been conducted.

Additionally, as available grazing land has decreased due to increased conversion to crop land (Wright and Wimberly, 2013), rental rates for grazing land have also increased (Jansen and Wilson, 2016). Therefore, when summer grazing costs are increased, it may be economically beneficial to background calves in pens during the summer rather than on grass, or directly finish the cattle during the summer, following winter grazing.

The objective of this study was to evaluate the effects of backgrounding yearling steers on grass or in drylot pens, targeting different rates of gain within each, on

subsequent finishing performance, carcass characteristics, and profitability of yearling beef steers.

MATERIALS AND METHODS

All animal care and management procedures were approved by the University of Nebraska-Lincoln Institutional Animal Care and Use Committee.

A 2-year experiment was conducted utilizing 240 yearling steers each year (yr 1 initial BW = 249 kg, SD = 9; yr 2 initial BW = 242 kg, SD = 15). One steer was removed in yr 1 and 8 steers were removed in yr 2 due to illness or lameness not related to treatments. Treatments consisted of 5 summer management strategies with 4 replications of each treatment per year (12 steers per replication). In each year steers were purchased in the fall and transported to the University of Nebraska's feedlot at the Eastern Nebraska Research and Extension Center (**ENREC**) located near Mead, NE. Within 24-hr of arrival at the ENREC, cattle were processed, which consisted of vaccination for protection against infectious bovine rhinotracheitis caused by infectious bovine rhinotracheitis (IBR) virus, bovine viral diarrhea caused by bovine virus diarrhea (BVD) virus Types 1 and 2, and disease caused by parainfluenza3 (PI3) virus and bovine respiratory syncytial virus (BRSV) (Bovi-Shield Gold 5; Zoetis, Florham Park, New Jersey), control against gastrointestinal roundworms, lungworms, eyeworms, grubs, sucking lice, and mange mites; (Dectomax injectable; Zoetis) and prevention of blackleg caused by *Clostridium chauvoei*, malignant edema caused by *Clostridium septicum*, black disease caused by *Clostridium novyi*, gas-gangrene caused by *Clostridium sordellii*, enterotoxemia and enteritis caused by *Clostridium perfringens* Types B, C and D, and

disease caused by *Histophilus somni (Haemophilus* somnus; Ultrabac 7; Zoetis). Approximately two weeks after initial processing, all steers were revaccinated with a second dose of viral, bacterial, and clostridial vaccines (Bovi-Shiled Gold 5 and Ultrabac 7). Approximately 3 weeks after arrival and prior to grazing corn stalks, steers were limit fed a diet consisting of 50% alfalfa and 50% Sweet Bran (Cargill Wet Milling, Blair, NE) at 2.0% of BW for 5 days to equalize gut fill (Watson et al., 2013). Steers were then weighed on 2 consecutive days (d 0 and 1) and the average of those 2 days was used as initial winter BW (Stock et al., 1983).

Winter Phase

Steers grazed corn residue for 154 d in year 1 and 161 d in year 2 from November to mid-April. Throughout the winter, steers were supplemented with 2.5 kg of modified distillers grains plus solubles (**MDGS**) per steer daily that averaged 33% CP (DM-basis) daily in metal bunks. Winter supplementation rate was based off research conducted by Bondurant et al. (2016) evaluating effect of winter MDGS supplementation on subsequent performance, in which 3 amounts of MDGS were fed to yearlings while grazing corn residue. In addition to MDGS supplement, steers were fed a supplement supplying calcium, monensin and trace minerals. The trace mineral premix provided 1,500 IU of vitamin A, 3,000 IU of vitamin D, and 3.7 IU of vitamin E per gram daily and was 10% Mg, 6% Zn, 4.5% Fe, 2% Mn, 0.5% Cu, 0.3% I, and 0.05% Co. Monenisn (Rumensin 90, Elanco Animal Health, Greenfield, IN) was provided at 200 mg/steer daily. The MDGS and supplement were mixed daily prior to delivery. Available grazing days for each residue field was calculated from corn grain yield using estimates of

residue amount per bushel and grazing efficiency as reported by previous research (McGee et al., 2012). Yield, estimated forage availability (3.6 kg/25.4 kg of corn grain), and total area were multiplied to determine an estimate of total available forage for the corn residue field. Estimated available forage was divided by estimated DMI (4.54 kg/steer daily) of steers to determine the number of grazing days the field could support. Steers were implanted with 36 mg of zeranol (Ralgro; Merck Animal Health, Summit, NJ) on d 1 of the winter phase.

Summer Backgrounding Phase

At the conclusion of corn residue grazing, steers were placed in pens and limit fed a diet consisting of 50% alfalfa and 50% Sweet Bran at 2.0% of BW for 5 days to equalize gut fill. Steers were then weighed on 3 consecutive days (d -1, 0, and 1 of the summer phase) and the average of those 3 days was used as initial summer BW depending on treatment. Steers were blocked (n = 3) by the average of the d -1 and 0 BW, stratified by BW within block and assigned to 1 of 5 summer management strategies. There were 4 replications per treatment each year (1 light block, 2 middle blocks, and 1 heavy block) with 12 steers per replication. Treatments consisted of summer finished steers (**SHORT**), steers grazing smooth bromegrass and supplemented with dried distillers grains plus solubles (**DDGS**) at 0.6% of BW (**SUPP**), steers grazing smooth bromegrass with no supplement (**UNSUPP**), steers backgrounded in a pen to target ADG of 1.07 kg/d (**HI**), and steers backgrounded in a pen to target ADG of 0.76 kg/d (**LO**). The level of targeted gain in the HI and LO treatments was equal to a 10-yr average of SUPP and UNSUPP gains on brome pastures (Welchons et al., 2016).

Steers in the HI and LO treatments were placed in pens by replication and limit fed a common diet which consisted of 30% Sweet Bran, 35% MDGS, 31% wheat straw, and 4% supplement which provided trace minerals and vitamins (Table 1). The HI treatment steers were limit fed the common diet at 11.24% of initial summer metabolic BW while the LO calves were fed at 9.14% of initial summer metabolic BW. These diets were fed as a percent of metabolic BW in order to minimize differences in maintenance requirements due to size differences between year 1 and 2. As a percent of initial BW, HI cattle were fed at 2.08 and 2.07 in years 1 and 2, respectively while LO cattle were fed at 1.70 and 1.75 in years 1 and 2, respectively.

The SUPP and UNSUPP replicates were assigned randomly to smooth bromegrass pastures. Supplemented cattle were fed daily at 0800 in metal bunks located within each pasture. Each pasture area was divided into 6 paddocks that were separated by a single strand of electric fence and consisted of 0.33 ha/paddock for the SUPP treatments and 0.48 ha/paddock for the UNSUPP treatment. Paddocks were rotationally grazed and the grazing period was divided into 5 cycles with cycle 1 lasting 24 d and cycles 2, 3, and 4 lasting 36 d. Cycle 5 lasted 24 d in year 1 and 29 d in year 2. Cattle rotated paddocks every 4 d during cycles 1 and 5 and every 6 d during cycles 2, 3, and 4.

Pastures were stocked at a rate of 9.88 animal unit months (**AUM**)/ha for SUPP cattle and 6.82 AUM/ha for the UNSUPP cattle. Stocking rate was based off Watson et al. (2012) in which variable stocking rates were used to evaluate the effect of distillers supplementation on stocking rate. On the first day of each cycle, cattle were removed from pasture at 0700 to be poured with an insecticide (Standguard, Elanco Animal

Health) and weighed. Amount of DDGS delivered to SUPP cattle was updated using these interim weights, shrunk 4%.

In both years, SUPP, UNSUPP, HI, and LO calves were implanted with 36 mg of zeranol (Ralgro, Merck Animal Health) on d 1 of the summer phase and with Component E-S (Elanco Animal Health) on d 60 (SUPP and UNSUPP) or d 61 (HI and LO).

Finishing Phase

Summer finished steers (April – September) were fed a finishing ration for 146 d in year 1 and 133 d in year 2 and implanted with 200 mg progesterone and 20 mg estradiol (Component E-S, Elanco Animal Health) on d 1 and with 120 mg trenbolone acetate and 24 mg estradiol (Component TE-S, Elanco Animal Health) on d 60 of the finishing phase each year. Summer finished steers were adapted to a finishing diet which consisted of 51% high-moisture corn, 30% Sweet Bran, 10% MDGS, 5% wheat straw, and 4% supplement (Table 1). Supplement was formulated to provide 33 mg/kg of monensin (Rumensin, Elanco Animal Health) and 90 mg/steer of tylosin (Tylan, Elanco Animal Health) daily and also contained a trace mineral and vitamin package. Realtime ultrasonography (RTU) was used to assess 12^{th} rib fat at 0% and approximately 50 and 75% of days on feed (DOF) of the SHORT finishing period in order to calculate rate of fat deposition so that all treatments were slaughtered at equal fatness. In year 1 (2015), market conditions were such that cattle were being fed to fatter endpoints to maximize profitability per steer. In trying to match industry trends, SHORT steers were targeted to a 12^{th} rib fat endpoint of 1.52 cm. However, in year 2, the target endpoint was lowered to

1.40 cm due to difficulties observed with summer backgrounded yearlings reaching 1.52 cm of backfat.

Upon removal from bromegrass in September, SUPP and UNSUPP cattle were placed into pens and limit fed a diet consisting of 50% alfalfa and 50% Sweet Bran at 2.0% of BW for 5 days to equalize gut fill. Steers were then weighed on 3 consecutive days (d -1, 0, and 1 of the finishing phase) and the average of those 3 days was used as initial finishing BW depending on treatment. Steers on the HI and LO treatments remained in their respective pens and were switched to the limit fed diet the same day the SUPP and UNSUPP steers began limit feeding. Steers were adapted to the same finishing diet fed to SHORT steers previously discussed. Carcass real time ultrasonography (RTU) was used to assess 12th rib fat at beginning of the finishing period and at interim dates in the same manner as the SHORT treatment in order to harvest all treatments at equal fatness. Summer backgrounded treatments were implanted with Component TE-S approximately 90 days from slaughter. All steers were harvested at Greater Omaha Packing Co. (Omaha, NE). On day of harvest, HCW was recorded. Final BW was then calculated as HCW divided by a common dressing percent of 63%. Following a 48-hr chill, 12th rib fat, LM area, and marbling score were recorded. Yield grade was calculated using the following equation: Calculated YG (**YG**) = (2.5 + (0.98 × 12th rib fat thickness, cm) – (0.05 × LM area, cm^2) + (0.2 × KPH, %) + (0.0084 × HCW, kg)), with KPH assumed to be a constant 2.5% (USDA, 1997).

Economic Analyses

Economic assumptions were applied to each treatment with respect to days spent in each phase and costs associated with that treatment for each phase. All prices were compiled from the Livestock Marketing Information Center (Lakewood, CO) using USDA reports. Initial purchase price was the average Nebraska livestock auction price/45.4 kg in November for steer calves weighing 250 kg. Revenue was calculated on an individual carcass basis and then averaged by pen in order to reflect the effect of any premiums and discounts associated with changes in quality and yield grade due to with treatment. Carcass price received was the average 5-Area Market base carcass price for September 2012 to 2016 for SHORT cattle and for December to February 2012 to 2016 for HI, LO, SUPP, and UNSUPP cattle. Different carcass prices were used to reflect market changes associated with time of slaughter. Likewise, premiums and discounts for HCW, yield grade, and quality grade were calculated for the same periods. Interest rates reported by the Federal Reserve Bank of Kansas City for agricultural operating loans over the 5-year period averaged 5.4%. Interest was applied to half of the initial animal cost and the total of all other costs for each individual phase (winter, summer, and finishing).

Winter Phase

Daily cost of corn residue grazing was modified from Johnson (2013) and applied at a rate of $0.35/steer daily. Cost of MDGS was the average November 2012 to 2016 price per 908 kg (assuming 48% DM) in Nebraska (USDA-AMS, 2017) which equated to $175.22/908 kg DM or $0.088/0.454 kg. Total supplement cost per steer was then

calculated as MDGS supplemented per day multiplied by total number of days spent grazing corn residue each year.

Summer Phase

For the HI and LO treatments, yardage was charged at $0.45/steer daily. Diet costs were calculated for each ingredient using the average of those ingredients from April to September of 2012 to 2016. Diet cost was $179.82/908 kg or $0.090/0.454 kg of DM. To calculate daily cost of the ration for each treatment, the average DMI was used for year 1 and 2 as intake differed by less than 0.3 kg between years for each treatment. Daily ration cost was $1.56/steer and $1.27/steer for the HI and LO treatments, respectively.

The SUPP and UNSUPP cattle were charged differing yardage amounts to account for the extra labor associated with daily supplementation during summer grazing. Supplemented cattle were charged $0.20/steer daily while UNSUPP cattle were charged $0.10/steer daily. Pasture rent was charged at a rate of $379.39/ha (Jansen and Wilson, 2016). As stocking rate varied between treatments, daily pasture rent was also different ($0.93 and $1.37/steer daily for SUPP and UNSUPP cattle, respectively). Distillers grains cost was the average April to September price for Nebraska from 2012 to 2016 and equated to $189.78/908 kg or $0.095/0.454 kg of DM. All steers were charged $15/steer for health and processing costs.

Finishing Phase

Yardage during the finishing phase was charged at $0.45/steer daily for all treatments. Likewise, a $15/steer health and processing charge was also charged to all

treatments. Death loss across all phases was accounted for at 2.0% and trucking costs were applied at $5/steer. Due to different finishing times, diet costs differed for the SHORT treatment compared to the HI, LO, SUPP, and UNSUPP treatments. Diet ingredient cost for the SHORT treatment was calculated for April to September 2012 to 2016 while for the other treatments, finishing diet ingredient costs were calculated for September to February for the same years. Diet costs then were $204.66/908 kg of DM ($0.102/0.454 kg) for the SHORT treatment and $185.95/908 kg of DM ($0.093/0.454 kg) for the other treatments.

Overall Analyses

Net profitability was calculated as total revenue (base carcass price multiplied by HCW and plus or minus premiums and discounts associated with weight, quality grade or yield grade) minus total costs (initial purchase price plus winter, summer, and finishing costs). Cost of gain (COG) was calculated for each treatment and phase by dividing total costs associated with the phase by total BW gained during the phase.

Statistical Analyses

All performance and economic data were analyzed using the GLIMMIX procedure of SAS (SAS Institute Inc., Cary, NC). Summer management strategy, year, block within year, and summer management × year interaction were included in the model as fixed effects. Replicate within year (4/treatment each year) was the experimental unit. Differences were considered significant at $P < 0.05$. Tendencies are discussed at $P < 0.10$. There were significant treatment × year interactions for most

performance and economic measures, therefore results are presented by treatment within year.

RESULTS AND DISCUSSION

Winter Phase

Initial winter BW was similar across all treatments (P = 0.78; Table 3), however, steers were heavier in year 1 (252 kg) than in year 2 (242 kg; P < 0.01). Likewise, by design, ADG of steers supplemented with 2.5 kg/steer daily of MDGS while grazing corn residue did not differ across treatments (P = 0.95) but was greater in year 1 than in year 2 (0.84 vs. 0.80 kg/d; P < 0.01). Gillespie-Lewis et al. (2016) reported that heifer calves supplemented with 2.3 kg of wet distillers grains (**WDGS**) gained an average of 0.62 kg/d over a 2-year study while Bondurant et al. (2016) reported that heifers gained 0.74 and 0.81 kg/d over 2 winters while grazing corn residue when fed 2.27 kg/d of MDGS. Using an equation designed to predict ADG of calves dependent on level of distillers grains supplementation as a percent of BW while grazing corn residue, ADG in year 1 and year 2 would be expected to be 0.78 kg/d (Welchons and MacDonald, 2017). Overall, gains of calves grazing corn residue prior to be assigned to summer management strategy was consistent with previously reported gains at similar levels of supplementation.

Summer Backgrounding Phase

By design there was no difference in initial BW for the summer backgrounding phase for the HI, LO, SUPP, and UNSUPP treatments (P = 0.71; Table 3); however, there was a significant effect of year on initial BW (P < 0.01) with initial summer BW being less in year 2 than in year 1. This was due to lighter BW at the beginning of the

winter phase in year 2 and decreased ADG during the winter phase in comparison to year 1. There was a treatment × year interaction for ADG during the summer backgrounding phase ($P < 0.01$). In year 1, all four treatments had differing levels of gain with HI being the greatest (1.03 kg/d) followed by LO (0.81 kg/d), SUPP (0.73 kg/d), and UNSUPP (0.45 kg/d). In year 2, the HI and SUPP treatments had similar levels of ADG (0.94 and 0.90 kg/d, respectively), followed by the LO treatment (0.75 kg/d) and the UNSUPP treatment which was lowest (0.47 kg/d). For the HI and LO treatments, G:F did not differ ($P = 0.18$), but was greater in year 1 (0.127) than in year 2 (0.119; $P = 0.03$). At the end of the summer, SUPP cattle were 44 kg heavier than UNSUPP cattle in year 1 and 71 kg heavier in year 2. This is in agreement with Rolfe et al. (2011), who reported a 48 kg increase in BW at the end of the summer for calves supplemented with MDGS at 0.6% of BW while grazing native summer range for 136 d. Likewise, Watson et al. (2012) summarized 5 years of performance data of steer calves supplemented with DDGS at 0.6% of BW while grazing smooth bromegrass compared to unsupplemented steers. Supplemented steers were 40 kg heavier than unsupplemented steers at the conclusion of the grazing season which lasted between 156 and 158 d. While the relative difference in ADG between supplemented and unsupplemented treatments observed in year 1 is similar to that reported by Watson et al. (2012) (0.28 and 0.26 kg/d, respectively), ADG was less for the current study in both years. In year 2, the relative difference between SUPP and UNSUPP was 0.43 kg/d due to increased ADG of SUPP cattle compared to year 1 and no difference in ADG of UNSUPP cattle across years.

By design, the HI and SUPP, and the LO and UNSUPP were managed to have similar ADG. In year 1, the HI and LO treatments had gains close to predicted levels; however, ADG of the SUPP and UNSUPP was below predictions based on previous cattle performance with the same treatments applied. In year 2, ADG of both the HI and LO treatments decreased, compared to year 1, in a similar manner (0.09 kg/d for the HI and 0.06 kg/d for the LO) but did not differ from year 1 gains.

Finishing Phase

There was a treatment × year interaction for initial feedlot body weight ($P < 0.01$; Table 4) due to differing ADG during the summer backgrounding phase. In year 1, HI cattle had the greatest initial feedlot body weight (547 kg; $P < 0.01$) followed by LO (512 kg), SUPP (500 kg), and UNSUPP (456 kg). The SHORT treatment had the lowest initial feedlot body weight (382 kg), due to the treatment being finished during the summer rather than backgrounded further prior to finishing. In year 2, with similar ADG observed in the summer backgrounding phase, initial feedlot BW for the HI and SUPP treatments did not differ ($P = 0.32$) but were greater than LO (494 kg) and UNSUPP (452 kg; $P < 0.01$). As observed in year 1, due to being placed on the finishing ration in April, the SHORT treatment had the lowest initial feedlot BW (372 kg).

Interestingly, even though initial feedlot BW was different for the HI and SUPP treatments and for the LO and UNSUPP treatments in year 1, initial 12th rib fat did not differ between HI and SUPP or LO and UNSUPP ($P > 0.05$). Similarly, in year 2 there was no difference in initial 12th rib fat between the HI and SUPP and LO and UNSUPP

treatments ($P > 0.65$). In general, as ADG increases, fat accretion would be expected to increase as well (Hersom et al., 2004). However, this was not universally observed in the current study (Figure 1). For the HI, SUPP, and UNSUPP treatments, as ADG increased, so did fat accretion during the summer backgrounding period. However, the LO cattle in both years appear to be outliers. The reason for decreased 12th rib fat accretion for the LO cattle is unclear though the intake restriction imposed on the LO treatment may have altered the ratio of fat to muscle deposition.

There was no treatment × year interaction for DMI ($P = 0.84$). However, there was a main effect of treatment and year ($P < 0.01$). In both years, the four summer backgrounding treatments had greater DMI than the SHORT treatment ($P < 0.01$) but did not differ from one another ($P \geq 0.14$). Overall, DMI in year 1 was greater than DMI in year 2.

There was a treatment × year interaction for feedlot ADG and feed efficiency ($P < 0.01$). In year 1 there was no difference in ADG between the HI (1.72 kg/d), LO (1.70 kg/d), SUPP (1.67 kg/d), and UNSUPP (1.76 kg/d; $P \geq 0.23$) which were all less than the SHORT treatment (2.01 kg/d; $P < 0.01$). Similarly, in year 1 the SHORT treatment was the most efficient in the finishing phase (0.160; $P < 0.01$), while the other treatments did not differ from one another ($P \geq 0.36$). In year 2, the UNSUPP treatment had the greatest ADG (1.97 kg/d; $P < 0.01$) with no differences between the other treatments ($P \geq 0.26$). Feed efficiency was similar for the SHORT, SUPP, LO, and UNSUPP treatments ($P \geq 0.12$). Feed efficiency for the HI treatment was less than the SHORT and UNSUPP ($P \leq$

0.04) treatment but did not differ from the LO and SUPP treatments ($P \geq 0.36$). Recent research evaluating the effect of summer supplementation on finishing performance has reported that unsupplemented cattle exhibit compensatory gain during the finishing phase which negated the additional gain due to supplementation, suggesting supplementation was not neccessary (Lomas and Moyer, 2008; Rolfe et al., 2011; Gillespie-Lewis., 2016). Bohman (1955) defined compensatory growth as the accelerated and/or more efficient growth that commonly follows a period of growth restriction. Rolfe et al. (2011) reported that unsupplemented cattle tended to have greater finishing ADG of 0.06 kg/d compared to cattle supplemented with MDGS at 0.6% of BW while grazing Sandhills range while Lomas and Moyer (2008) reported an increase in gain of 0.12 kg/d during the finishing period for unsupplemented cattle grazing bromegrass compared to cattle supplemented with DDGS at 0.5% of BW.

However, in year 1 there was no compensatory growth as evidenced by similar finishing ADG among summer backgrounded treatments regardless of restriction or severity of restriction. Of note, however, the relative difference in finishing ADG between the SUPP and UNSUPP treatments was 0.09 kg/d which was greater than that reported by Rolfe et al. (2011), though it was not statistically significant ($P = 0.23$). This numerical difference in gain lead to a 25% compensation for the UNSUPP compared to the SUPP treatment. Additionally, we hypothesized that the LO treatment would have increased ADG during the finishing period as a result of compensatory growth, relative to the HI treatment, but this was not observed (0.02 kg/d less).

In contrast to research reporting differences in finishing ADG for cattle supplemented with distillers grains during the summer prior to finishing compared to unsupplemented cattle, Morris et al. (2006) and Funston et al. (2007) reported no differences in finishing ADG or feed efficiency for supplemented compared to unsupplemented steers. Griffin et al. (2012) supplemented calves grazing cool-season meadow in the Nebraska Sandhills with DDGS at 0, 0.6, or 1.2% of initial BW. A linear increase in grazing ADG occurred as a result of supplementation. Furthermore, there were no differences in finishing ADG or G:F due to DDGS supplementation. Similarly, Greenquist et al. (2009) reported no differences in finishing ADG or G:F for steers supplemented with DDGS at 0.6% of BW while grazing bromegrass compared to unsupplemented steers. Additionally, Funston et al. (2007) and Rolfe et al. (2011) reported that as a result of increased BW when entering the feedlot, calves supplemented during summer grazing of native Sandhills range required fewer DOF to reach equal fat thickness as unsupplemented calves. This is in agreement with the current study in which ADG during the finishing period was similar in both years for the HI and LO treatments, and the HI treatment required fewer DOF to reach an equal fat endpoint.

In year 2, compensatory gain was observed for the UNSUPP treatment. The UNSUPP treatment compensated 103% compared to the SUPP treatment. In a review evaluating the effect of previous grazing nutrition on the finishing performance of calves, Drouillard and Kuhl (1999) reported that there was a lack of consistency in the published research regarding effect of supplementation of grazing cattle on subsequent feedlot performance. The authors did note that, in general, compensatory growth in the feedlot

was more widely observed for cattle that had been previously grazing higher quality forages similar to the forages that cattle would have been grazing in the research previously discussed. It is unclear why the UNSUPP treatment exhibited compensatory growth during the finishing phase in year 2 but not year 1. Confounding effects due to year can be attributed to differences in temperature, precipitation, and animals. Across the two years of this study (2015 and 2016), measures of environment were investigated as possible reasons for differences in performance. However, adjusted thermal humidity index (71.6 and 78.5 for years 1 and 2, respectively; Mader et al., 2006) and precipitation levels (85 and 75 cm for years 1 and 2, respectively) were similar.

There was a treatment × year interaction for final BW ($P < 0.01$). In year 1, final BW was greatest for the HI, LO, and SUPP treatments with the UNSUPP and SHORT treatments being lighter than the HI and LO but not different from the SUPP. In year 2 the LO treatment had the greatest final BW but there were no differences between other summer backgrounded treatments ($P \geq 0.55$). Summer finished yearlings had the lightest final BW ($P < 0.01$).

There was a treatment × year interaction for total system ADG ($P < 0.01$). In year 1 the SHORT treatment had the greatest system ADG followed by the HI and LO. The SUPP treatment was lower than the HI ($P < 0.01$) but not different from the LO ($P = 0.17$). The UNSUPP treatment had the lowest system ADG. In year 2, the SHORT and LO treatments had the greatest system ADG followed by the HI and SUPP treatments ($P < 0.05$). Once again, the UNSUPP treatment had the lowest system ADG. Differences in

system ADG for treatments relative to one another is attributed to differences in the summer backgrounding and/or finishing phases between years.

Carcass Characteristics

There was a treatment × year interaction for HCW ($P < 0.01$). In year 1 the HI, LO, and SUPP treatments had the heaviest HCW followed by the UNSUPP and SHORT treatments which were lighter than the HI and LO ($P < 0.05$). The SHORT treatment was not different from the SUPP treatment ($P = 0.23$) while the UNSUPP treatment tended to be lighter ($P = 0.06$). In year 2 the LO treatment had the greatest HCW ($P < 0.01$) followed by the HI, SUPP, and UNSUPP treatments which were all greater than the SHORT treatment ($P < 0.01$).

There was a treatment × year interaction ($P < 0.01$) for LM area. In year 1 SHORT was greater than UNSUPP ($P = 0.01$) but all other treatments were similar to both SHORT and UNSUPP ($P \geq 0.32$). In year 2 the SHORT treatment had the smallest LM area with the HI, LO, and SUPP having the greatest ($P < 0.04$). The UNSUPP was less than the HI ($P = 0.03$) and tended to be smaller than LO ($P = 0.06$) but was not different from SUPP ($P = 0.61$). There was a main effect of treatment on marbling score ($P < 0.01$). In both years the LO and UNSUPP treatments had the highest marbling score followed by the HI and SUPP treatments which did not differ from the UNSUPP ($P \geq 0.32$). The SHORT treatment had the lowest marbling score which did not differ from the HI and SUPP ($P \geq 0.11$). There was a main effect of treatment on calculated YG (P < 0.05). The LO treatment had the highest YG which tended to be greater than the SUPP

treatment (P = 0.08) and was greater than the YG of the SHORT, HI, and UNSUPP ($P \leq$ 0.04) treatments which were all similar to the SUPP ($P \geq 0.27$). There was a tendency for a treatment × year interaction for empty body fat (P = 0.08). In year 1 there were no differences among treatments ($P \geq 0.13$). However, in year 2 the LO treatment had greater empty body fat than the other treatments ($P \leq 0.04$). Occurrence of yield grade 4 and above was greater than 20% for all treatments in both years except for the SHORT treatment in year 2. Additionally, occurrence of overweight carcasses (> 454 kg) was 8.3% and 0% for the SHORT treatment in years 1 and 2, respectively. For the summer backgrounded treatments in year 1, overweight carcasses occurred at a rate of 41.7, 50.0, 27.1, and 6.3% for the HI, LO, SUPP, and UNSUPP treatments, respectively. In year 2, occurrence rate was 31.9, 66.7, 27.3, and 22.7% for the same treatments. Feuz (2002) suggested that the added economic benefits resulting from increased HCW and marbling were such that discounts could be applied on up to 15% of cattle before the benefits were negated. Wilken et al. (2015) reported that feeding cattle to increased DOF increased profitability due to increased HCW and QG premiums which offset overweight and yield grade discounts. However, Bondurant (2017) reported that the profitability of feeding cattle to fatter endpoints than normal (1.75 cm or 1.47 cm vs 1.27 cm of 12^{th} rib fat) varied depending on market conditions such as feeder and carcass price, corn price, and discounts associated with overweight and yield grade 4 carcasses. Additionally, Bondurant (2017) reported that feeding cattle to an increased fat endpoint did not affect QG premiums received. Given that it is difficult to estimate the changes across treatments in quality and yield grade associated with changes in HCW and DOF, the threshold of

where added benefit turns to loss is unclear in the current study. However, it can be reasonably suggested that a lower fat endpoint may have been appropriate for the cattle in this study.

Increased HCW for fall finished yearlings has been previously reported (Adams et al. (2010). Adams et al. (2010) reported that steers finished in the summer had decreased HCW compared to yearlings that grazed during the summer and were then finished in the fall. While differences in fat thickness were not significant in that study, the fall finished yearlings had numerically less 12^{th} rib fat than the summer finished yearlings. Tedeschi et al. (2004) emphasized the importance of evaluating cattle at equal fat endpoints. In addition, Bruns et al. (2004) and May et al. (1992a) reported that in general, as DOF increase, so does HCW, QG, and fat thickness. Therefore, it can be expected that if those treatments were fed to equal fatness, the difference in HCW would be even greater. In year 1 of the current study, HCW of the SHORT treatment did not differ significantly from all the summer backgrounded treatments; however, numerically those cattle were much fatter. In year 2, when cattle were fed to a more similar fat endpoint, HCW of the SHORT cattle was decreased, in agreement with the findings of Adams et al. (2010). Within the summer backgrounded treatments, when fed to equal endpoints, HCW was similar with the exception being the LO treatment in year 2. Increased HCW was a result of increased DOF needed to reach the target fat endpoint. The increased days required to reach a similar 12^{th} rib fat as other treatments combined with the increase in marbling score relative to other treatments may suggest that the LO cattle deposited more fat

intramuscularly than subcutaneously. Lower marbling scores for summer finished yearlings compared to fall yearlings were also reported by Adams et al. (2010).

Economic Analysis

Winter Phase

Initial purchase cost was greater in year 1 (Table 6) than in year 2 ($P < 0.01$; Table 7) due to differences in initial BW. By design winter costs did not differ among treatments; however, they were greater in year 2 than in year 1 due to a 7d longer corn residue grazing period.

Summer Backgrounding Phase

There was no treatment × year interaction for total summer costs ($P = 0.42$). In both years HI had the greatest costs ($333.01 in year 1 and $343.31 in year 2) followed by LO ($286.19 in year 1, $294.97 in year 2), SUPP ($278.83 in year 1, $288.55 in year 2), and UNSUPP ($244.62 in year 1, $251.98 in year 2). However, due to differences in ADG of treatments between years there was a significant treatment × year interaction for summer COG ($P < 0.02$). In year 1, UNSUPP had the highest COG ($1.57/0.454 kg; $P < 0.01$) followed by SUPP ($1.10/.454 kg) and LO ($1.03/0.454 kg) with the HI treatment having the lowest summer COG ($0.94/.454 kg) though it did not differ from the LO treatment ($P = 0.19$). In year 2, UNSUPP once again had the highest COG ($1.51/0.454 kg; $P < 0.01$) followed by the LO and HI treatments ($1.10 and $1.02/0.454 kg, respectively) with the SUPP having the lowest summer COG ($0.90/0.454 kg; $P \leq 0.06$). Of note is the effect the change in summer ADG of the SUPP treatment had on summer

COG. An increase in ADG of 0.17 kg/d decreased COG by $0.20/0.454 kg). Additionally, the relatively small decrease in ADG of 0.06 kg/d for the LO treatment increased COG by $0.07/0.454 kg, which when multiplied by total BW gain during the summer backgrounding phase would increase costs by $25.29/steer.

Finishing Phase

There was a treatment × year interaction for finishing costs and finishing COG ($P < 0.01$). In year 1, SHORT cattle had the highest finishing costs ($526.04/steer) but the lowest finishing COG (0.81/0.454 kg). The increase in total finishing costs was due to longer DOF and increased diet cost as a result of time of year when SHORT cattle were finished. However, due to increased ADG, finishing COG was decreased compared to the summer backgrounded treatments. Total finishing costs were not different for the LO, SUPP, and UNSUPP treatments ($P \geq 0.73$). The HI treatment had the lowest finishing costs of the summer backgrounded treatments ($364.88; $P > 0.01$), resulting from similar DMI and decreased DOF, but finishing COG did not differ among summer backgrounded treatments ($P \geq 0.32$). In year 2, the SHORT ($446.36/steer), LO ($471.91/steer), and UNSUPP ($416.55/steer) had the greatest finishing costs while the HI and SUPP treatments had the lowest finishing costs ($338.03 and 337.26/steer, respectively; $P < 0.01$). Decreased finishing costs for the SHORT treatment in year 2 relative to year 1 were a result of decreased DOF and DMI in year 2. However, although there was a decrease in finishing costs, finishing COG increased for the SHORT treatment due to decreased ADG in year 2 compared to year 1. In year 2, the SUPP, HI, and SHORT had

the highest finishing COG ($0.93, 0.91, 0.89/0.454 kg, respectively) which were higher than the UNSUPP treatment ($0.80/0.454 kg; $P < 0.01$). The LO treatment had a finishing COG ($0.85/0.454 kg) lower than SUPP ($P = 0.03$) but similar to all other treatments ($P \geq 0.12$).

Total System

There was a treatment × year interaction for total system costs and COG ($P < 0.01$). In year 1, SHORT cattle had the lowest total costs at $1829.89/steer ($P < 0.01$) while the summer backgrounded treatments had similar total costs ($P \geq 0.22$). Total COG was greatest for the UNSUPP treatment ($2.20/0.454 kg; $P \leq 0.03$) followed by the SUPP, LO, and HI treatments which did not differ from one another ($P \geq 0.13$). Short yearlings had a total COG lower than the UNSUPP and SUPP treatments ($P \leq 0.03$) but did not differ from the HI and LO treatments ($P \geq 0.41$).

In year 2, total costs were once again lowest for the SHORT treatment ($1728.96/steer; $P < 0.01$). Total costs per steer were greatest for the LO treatment ($2048.76/steer) followed by HI, UNSUPP, and SUPP. Total costs for the SUPP treatment were lower than the HI treatment with the UNSUPP being intermediate between the two. Total COG in year 2 was lowest for the LO ($1.84/0.454 kg) and SUPP ($1.95/0.454 kg) treatments with the UNSUPP ($2.01/0.454 kg) and HI ($1.97/0.454 kg) being similar to the SUPP treatment but higher than the LO. Short yearlings had the highest total COG ($2.20/0.454 kg).

Decreases in total COG for the SUPP and UNSUPP treatments in year 2 relative to year 1 are a result of increases in ADG (during the summer and finishing phase for SUPP cattle and during the finishing phase for UNSUPP) and decreased DOF to reach similar endpoint (SUPP). Decreases in total COG for the LO treatment are a result of increased final BW due to increased DOF to reach the desired fat endpoint. Increase in total COG for the SHORT treatment is due to decreased ADG in the finishing phase compared to year 1.

There was a significant treatment × year interaction for both total revenue and net profit ($P < 0.01$). In both years the SHORT treatment had the lowest total revenue ($1862.07 and $1657.25 in years 1 and 2, respectively; $P < 0.01$). In year 1, total revenue for the LO, HI, and SUPP treatments did not differ ($P \geq 0.22$) with the UNSUPP generating less revenue than the LO and HI ($P < 0.07$) but similar to the SUPP ($P = 0.20$). In year 2 however, LO, HI, and UNSUPP had similar revenue ($P \leq 0.11$) with the SUPP treatment being less than the LO ($P = 0.04$) but similar to the HI and UNSUPP ($P \geq 0.57$).

In year 1, net profit tended to be greater ($P \leq 0.09$) for the SHORT and LO treatments ($32.19 and 24.92/steer, respectively) compared to the UNSUPP treatment (-$54.65/steer). Net profit for the HI ($20.17/steer) and SUPP (- $34.10/steer) did not differ from other treatments ($P \geq 0.12$). In year 2, net profit for the summer backgrounded treatments ($89.27, 59.39, 38.33, and 38.12/steer for the SUPP, UNSUPP, HI, and LO treatments, respectively) was greater than the SHORT treatment ($P < 0.01$) but did not

differ among summer backgrounded treatments ($P \geq 0.26$). Due to differences in DOF and 12th rib fat in year 1 for the SHORT treatment compared to the summer backgrounded treatments, it is difficult to compare profitability although Bondurant (2017) and May et al. (1992b) reported that cattle fed to fatter endpoints had greater carcass value relative to cattle finished at a less fat endpoint. However, among summer backgrounded treatments, net profit over the two years illustrates the effect that changes in performance, both within system phase and across the entire system, can have on profitability of a management strategy. The net profit generated by the HI and LO treatments stayed relatively constant in both years, especially when compared to changes in profitability of other treatments. Though total revenue decreased by $21.77/steer for the HI treatment from year 1 to 2, the increase in finishing ADG and feed efficiency decreased costs enough to offset the decrease in revenue. For the LO treatment, revenue per steer increased by $24.46/steer as a result of increased carcass size in year 2 needed for the LO treatment to reach 1.40 cm of 12th rib fat. Total costs also increased for the LO treatment as a result of increased DOF in year 2, though the cost associated with the increased DOF was partially offset by the increase in ADG and G:F in year 2.

For the SUPP and UNSUPP treatments, there were large differences in profitability between years 1 and 2. In year 1, neither treatment was profitable, however in year 2, SUPP and UNSUPP profitability increased by $123.37 and $114.04 per steer, respectively. For the SUPP treatment, this was largely due to increased feed efficiency during the finishing period while requiring similar DOF between years. Therefore, total costs were decreased while revenue remained similar between years. For the UNSUPP

treatment, increase in profitability was a result of increased ADG and G:F during the finishing phase while requiring similar DOF to reach equal fat thickness in both years. This resulted in a decrease in total costs and an increase in total revenue resulting from increased HCW.

IMPLICATIONS

Steers backgrounded through the summer and finished in the fall had increased HCW and typically required fewer DOF to reach a similar fat endpoint as summer finished steers. Backgrounding yearlings in drylot pens during the summer resulted in more consistent performance across the 2 years than grazing steers on grass. When fed at either a high or low rate of gain in the drylot pens, steers had similar ADG and G:F, although steers backgrounded at a higher rate of gain required fewer DOF. Steers supplemented with DDGS at 0.6% of BW while grazing bromegrass had greater ADG than unsupplemented steers during the summer. Differences in compensatory growth of the unsupplemented steers between years are supported by variability in previous research evaluating compensatory growth. Thus, profitability of treatments backgrounded at a slower rate of gain during the summer, relative to treatments backgrounded at a higher rate of gain, is heavily influenced by whether or not compensatory growth is exhibited. Growing systems targeting compensatory growth may not yield consistent results across years.

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Table 1. Composition of backgrounding diet fed to pen grown steers and finishing diet (DM-basis) fed to all steers

Ingredient	Backgrounding	Finishing
High-moisture corn	-	51.0
Sweet Bran[1]	30.0	30.0
MDGS[2]	35.0	10.0
Wheat straw	31.0	5.0
Supplement[3]	-	-
Fine-ground corn	1.52	1.79
Limestone	2.00	1.72
Salt	0.300	0.300
Tallow	0.100	0.100
Beef trace minerals[4]	0.050	0.050
Vitamins A-D-E[5]	0.015	0.015
Monensin[6]	-	0.0165
Tylosin[7]	-	0.0102

[1] Cargill Corn Milling, Blair, Nebraska.
[2] Modified distillers grains plus solubles.
[3] Included at 4% total diet DM.
[4] Premix contained 10% Mg, 6% Zn, 4.5% Fe, 2% Mn, 0.5% Cu, 0.3% I, and 0.05% Co.
[5] Premix contained 1,500 IU of vitamin A, 3,000 IU of vitamin D, and 3.7 IU of vitamin E per g.
[6] Rumensin 90, Elanco Animal Health, Indianapolis, IN. Formulated to provide 33 mg/kg.
[7] Tylan 40, Elanco Animal Health, Indianapolis, IN. Formulated to provide 90 mg/steer daily.

Table 2. Economic assumptions applied to short and long yearling steers under differing summer management strategies preceded by corn residue grazing and followed by feedlot finishing

	Treatments[1]				
Item[2]	SHORT	HI	LO	SUPP	UNSUPP
Winter					
Corn residue rent, $/steer daily[3]	0.35	0.35	0.35	0.35	0.35
Supplement cost, $/steer daily[4]	0.48	0.48	0.48	0.48	0.48
Summer					
Yardage, $/steer daily[3]	-	0.45	0.45	0.20	0.10
Health, $/steer	-	15.00	15.00	15.00	15.00
Diet/Supplement cost, $/steer daily[5]	-	1.56	1.27	0.39	-
Land rent, $/steer daily[6]	-	-	-	0.93	1.37
Finishing					
Yardage, $/steer daily[3]	0.45	0.45	0.45	0.45	0.45
Health, $/steer	15.00	15.00	15.00	15.00	15.00
Diet cost, $/908 kg[7]	204.66	185.95	185.95	185.95	185.95
Steer Prices					
Feeder calf price, $/45.4 kg[8]	201.24	210.24	210.24	210.24	210.24
Base carcass price, $/45.4 kg[9]	203.27	216.18	216.18	216.18	216.18

[1] Treatments = short yearlings (SHORT), high level of backgrounding gain in pen (HI), low level of backgrounding gain in pen (LO), supplemented with DDGS at 0.6% of BW while grazing smooth bromegrass (SUPP), grazed smooth bromegrasss with no supplement (UNSUPP).
[2] Pricing data retrieved from Livestock Marketing Information Center, Lakewood, CO. Utilizing USDA market data from November 2012 – March 2017.
[3] Includes animal care and supplement delivery cost.
[4] Cost of MDGS supplemented at 1.0% of initial steer BW.
[5] Cost of diet fed at 11.24% (HI) or 9.14% (LO) of metabolic BW or supplemented at 0.6% of BW (SUPP).
[6] $379.39/ha
[7] Diet cost per 908 kg on a DM basis.
[8] Price paid based off Nebraska combined auction reports for October 2012 to 2016.
[9] Price based off 5-Area Summary for September (SHORT) or December to February (HI, LO, SUPP, UNSUPP).

Table 3. Effect of growing system on summer performance

	Treatments[1]						*P* - Value		
Item,	SHORT	HI	LO	SUPP	UNSUPP	SEM	Trt	Year	Int[2]
Winter, year 1[3]									
Initial BW, kg	248	249	248	250	249	1.67	0.78	< 0.01	0.74
ADG, kg	0.84	0.84	0.85	0.84	0.84	0.01	0.95	< 0.01	0.84
Winter, year 2[3]									
Initial BW, kg	243	243	240	241	242	1.67	0.78	< 0.01	0.74
ADG, kg	0.79	0.79	0.80	0.81	0.79	0.01	0.95	< 0.01	0.84
Summer, year 1[4]									
Initial BW, kg	-	383	383	383	383	1.41	0.71	< 0.01	0.71
ADG, kg	-	1.03[a]	0.81[b]	0.73[c]	0.45[d]	0.023	< 0.01	0.73	< 0.01
G:F	-	0.129	0.125	-	-	0.003	0.18	0.03	0.87
Summer, year 2[4]									
Initial BW, kg	-	372	369	373	371	1.41	0.71	< 0.01	0.71
ADG, kg	-	0.94[a]	0.75[b]	0.90[a]	0.47[c]	0.023	< 0.01	0.73	< 0.01
G:F	-	0.122	0.118	-	-	0.003	0.18	0.03	0.87

[abcd] Means within a row without a common superscript are significantly different ($P < 0.05$).
[1] Treatments = short yearlings (SHORT), high level of backgrounding gain in pen (HI), low level of backgrounding gain in pen (LO), supplemented with DDGS at 0.6% of BW while grazing smooth bromegrass (SUPP), grazed smooth bromegrasss with no supplement (UNSUPP).
[2] Treatment × year interaction.
[3] Winter = corn stalk residue grazing for 154 days in year 1 and 161 days in year 2.
[4] Summer = Respective treatment for 156 days in year 1 and 161 days in year 2.

Table 4. Effect of growing system on finishing performance

	Treatments[1]						*P* - Value		
Item,	SHORT	HI	LO	SUPP	UNSUPP	SEM	Trt	Year	Int[2]
Year 1									
Initial BW, kg	382^{e}	547^{a}	513^{b}	500^{c}	456^{d}	3.60	< 0.01	0.11	< 0.01
Initial 12th Rib fat, cm	0.274^{c}	0.528^{a}	0.300^{bc}	0.471^{a}	0.357^{b}	0.02	< 0.01	0.21	< 0.01
Final BW, kg[3]	676^{b}	713^{a}	713^{a}	697^{ab}	664^{b}	12.4	< 0.01	0.37	< 0.01
DMI, kg/d	12.5^{b}	13.9^{a}	14.0^{a}	14.2^{a}	14.4^{a}	0.16	< 0.01	< 0.01	0.84
ADG, kg	2.01^{a}	1.72^{b}	1.70^{b}	1.67^{b}	1.76^{b}	0.05	0.06	0.97	< 0.01
G:F	0.160^{a}	0.124^{b}	0.121^{b}	0.118^{b}	0.122^{b}	0.004	< 0.01	< 0.01	< 0.01
DOF[4]	146	97	118	118	118	-	-		-
System ADG, kg[5]	1.39^{a}	1.10^{b}	1.05^{bc}	1.01^{c}	0.94^{d}	0.02	< 0.01	0.12	< 0.01
Year 2									
Initial BW, kg	372^{d}	528^{a}	494^{b}	523^{a}	452^{c}	3.60	< 0.01	0.11	< 0.01
Initial 12th Rib fat, cm	0.194^{c}	0.525^{a}	0.296^{b}	0.531^{a}	0.283^{b}	0.02	< 0.01	0.21	< 0.01
Final BW, kg[3]	601^{c}	698^{b}	751^{a}	687^{b}	689^{b}	12.4	< 0.01	0.37	< 0.01
DMI, kg/d	11.4^{b}	12.7^{a}	12.4^{a}	12.7^{a}	12.9^{a}	0.16	< 0.01	< 0.01	0.84
ADG, kg	1.72^{b}	1.77^{b}	1.80^{b}	1.73^{b}	1.97^{a}	0.05	0.06	0.97	< 0.01
G:F	0.152^{a}	0.139^{b}	0.145^{ab}	0.142^{ab}	0.153^{a}	0.004	< 0.01	< 0.01	< 0.01
DOF[4]	133	96	142	96	121	-	-		-
System ADG, kg[5]	1.16^{a}	1.05^{b}	1.11^{a}	1.04^{b}	0.98^{c}	0.02	< 0.01	0.12	< 0.01

[abcd] Means within a row without common superscript are significantly different ($P < 0.05$).

[1] Treatments = short yearlings (SHORT), high level of backgrounding gain in pen (HI), low level of backgrounding gain in pen (LO), supplemented with DDGS at 0.6% of BW while grazing smooth bromegrass (SUPP), grazed smooth bromegrasss with no supplement (UNSUPP).

[2] Treatment × year interaction.

[3] Final BW = HCW ÷ 0.63.

[4] Treatments were fed to same target 12th rib fat thickness.

[5] Total BW gain ÷ total days in system.

Table 5. Effect of growing system on carcass characteristics

	Treatments[1]						*P* - Value		
Item,	SHORT	HI	LO	SUPP	UNSUPP	SEM	Trt	Year	Int[2]
Year 1									
HCW, kg	426^{b}	449^{a}	449^{a}	439^{ab}	418^{b}	7.81	< 0.01	0.31	< 0.01
LM area, cm^2	89.0^{a}	87.7^{ab}	85.8^{ab}	87.1^{ab}	84.5^{b}	1.16	0.19	0.08	< 0.01
12^{th} Rib fat, cm	1.60^{x}	1.40^{xy}	1.37^{xy}	1.47^{xy}	1.32^{y}	0.05	0.02	0.12	0.18
Marbling Score[3]	481^{z}	484^{yz}	514^{x}	491^{yz}	492^{xy}	10.8	< 0.01	0.94	0.23
Calculated YG[4]	3.74^{y}	3.80^{y}	3.86^{x}	3.84^{xy}	3.60^{y}	0.07	< 0.05	0.60	0.24
EBF, %[5]	31.9	31.5	31.8	31.9	30.8	0.42	0.12	0.31	0.08
Year 2									
HCW, kg	379^{c}	437^{b}	473^{a}	433^{b}	434^{b}	7.81	< 0.01	0.31	< 0.01
LM area, cm^2	81.3^{c}	88.4^{a}	87.7^{ab}	85.2^{ab}	84.5^{b}	1.16	0.19	0.08	< 0.01
12^{th} Rib fat, cm	1.42^{x}	1.37^{xy}	1.42^{xy}	1.32^{xy}	1.30^{y}	0.05	0.02	0.12	0.18
Marbling Score[3]	442^{z}	488^{yz}	538^{x}	483^{yz}	511^{xy}	10.8	< 0.01	0.94	0.23
Calculated YG[4]	3.6^{y}	3.6^{y}	4.0^{x}	3.7^{xy}	3.7^{y}	0.07	< 0.05	0.60	0.24
EBF, %[5]	30.4^{b}	31.2^{b}	32.6^{a}	31.0^{b}	31.3^{b}	0.42	0.12	0.31	0.08

^{abcd} Means within a row without common superscripts are significantly different for treatment × year interaction ($P < 0.05$).
^{xyz} Means within a row without common superscripts are significantly different for main effect of treatment ($P < 0.05$).
[1] Treatments = short yearlings (SHORT), high level of backgrounding gain in pen (HI), low level of backgrounding gain in pen (LO), supplemented with DDGS at 0.6% of BW while grazing smooth bromegrass (SUPP), grazed smooth bromegrasss with no supplement (UNSUPP).
[2] Treatment × year interaction.
[3] Marbling Score: 400=Small^{00}, 500=Modest^{00}.
[4] Calculated as 2.5 + (0.098 x 12^{th} rib fat) + (0.2 x 2.5 (KPH)) + (0.0084 x HCW) – (0.05 x LM area).
[5] Calculated as 17.76207 + (4.68142 x 12^{th} rib fat) + (0.01945 x HCW) + (0.81855 x QG) – (0.06754 x LM area) from Guiroy et al., 2001.

Table 6. Economic analysis for yearling steers under differing summer management strategies during year 1

	Treatments[1]						*P* – value		
Item[2]	SHORT	HI	LO	SUPP	UNSUPP	SEM	Trt	Year	Int[3]
Year 1									
Purchase cost[4]	1150.25	1153.18	1148.98	1157.39	1152.66	7.78	0.75	< 0.01	0.74
Winter cost[5]	128.11	128.11	128.11	128.11	128.11	-	-	< 0.01	-
Summer cost[6]	-	333.01^{a}	286.19^{b}	278.83^{c}	244.62^{d}	0.66	< 0.01	< 0.01	0.42
Summer COG[7]	-	0.94^{c}	1.03^{bc}	1.10^{b}	1.57^{a}	0.05	< 0.01	0.51	< 0.02
Finishing cost[8]	526.04^{a}	364.88^{c}	437.83^{b}	442.98^{b}	447.31^{b}	19.54	< 0.01	< 0.01	0.01
Finishing COG[9]	0.81^{b}	1.00^{a}	0.99^{a}	1.02^{a}	0.97^{a}	0.03	< 0.01	< 0.01	< 0.01
Total Cost[10]	1829.89^{b}	2013.92^{a}	2037.50^{a}	2043.97^{a}	2009.21^{a}	20.11	< 0.01	< 0.01	< 0.01
Total COG[11]	1.95^{c}	1.98^{bc}	1.99^{bc}	2.08^{b}	2.20^{a}	0.04	0.02	0.25	< 0.01
Total Revenue[12]	1862.07^{c}	2034.09^{ab}	2062.42^{a}	2009.87^{ab}	1954.57^{b}	30.29	< 0.01	0.26	< 0.01
Net Profit[13]	32.19	20.17	24.92	-34.10	-54.65	32.11	0.60	0.20	< 0.01

[1] Treatments = short yearlings (SHORT), high level of backgrounding gain in pen (HI), low level of backgrounding gain in pen (LO), supplemented with DDGS at 0.6% of BW while grazing smooth bromegrass (SUPP), grazed smooth bromegrasss with no supplement (UNSUPP).
[2] All economic analyses items presented as $ per steer.
[3] Test for treatment × year interaction.
[4] Calculated by multiplying initial BW/45.4 kg by Nebraska livestock auction sales prices in 45.4 kg weight groups for November.
[5] Total winter supplement cost + corn residue grazing rent and interest.
[6] Total summer diet or supplement cost + yardage, health costs, land rent, and interest.
[7] Total summer cost / BW gained during the summer phase.
[8] Total diet, yardage, health, and interest costs during the finishing phase.
[9] Total finishing cost / BW gained during the finishing phase.
[10] Total of winter, summer, and finishing costs.
[11] Total costs / BW gained during the winter, summer, and finishing phases.
[12] Calculated by multiplying HCW/45.4 kg times 5-Area Market prices/45.4 kg.
[13] Total revenue – total costs.

Table 7. Economic analysis for yearling steers under differing summer management strategies during year 2

	Treatments[1]						*P* – value		
Item[2]	SHORT	HI	LO	SUPP	UNSUPP	SEM	Trt	Year	Int[3]
Year 2									
Purchase cost[4]	1124.22	1123.90	1109.85	1112.80	1122.02	7.78	0.75	< 0.01	0.74
Winter cost[5]	133.93	133.93	133.93	133.93	133.93	-	-	< 0.01	-
Summer cost[6]	-	343.31[a]	294.97[b]	288.55[c]	251.98[d]	0.66	< 0.01	< 0.01	0.42
Summer COG[7]	-	1.02[bc]	1.10[b]	0.90[c]	1.51[a]	0.05	< 0.01	0.51	< 0.02
Finishing cost[8]	446.36[a]	338.03[b]	471.91[a]	337.26[b]	416.55[a]	19.54	< 0.01	< 0.01	0.01
Finishing COG[9]	0.89[ab]	0.91[ab]	0.85[bc]	0.93[a]	0.80[c]	0.03	< 0.01	< 0.01	< 0.01
Total Cost[10]	1728.96[d]	1973.99[b]	2048.76[a]	1907.02[c]	1961.27[bc]	20.11	< 0.01	< 0.01	< 0.01
Total COG[11]	2.20[a]	1.97[b]	1.84[c]	1.95[bc]	2.01[b]	0.04	0.02	0.25	< 0.01
Total Revenue[12]	1657.25[c]	2012.32[ab]	2086.88[a]	1996.30[b]	2020.66[ab]	30.29	< 0.01	0.26	< 0.01
Net Profit[13]	-71.72[b]	38.33[a]	38.12[a]	89.27[a]	59.39[a]	32.11	0.60	0.20	< 0.01

[1] Treatments = short yearlings (SHORT), high level of backgrounding gain in pen (HI), low level of backgrounding gain in pen (LO), supplemented with DDGS at 0.6% of BW while grazing smooth bromegrass (SUPP), grazed smooth bromegrasss with no supplement (UNSUPP).
[2] All economic analyses items presented as $ per steer.
[3] Test for treatment × year interaction.
[4] Calculated by multiplying initial BW/45.4 kg by Nebraska livestock auction sales prices in 45.4 kg weight groups for November.
[5] Total winter supplement cost + corn residue grazing rent and interest.
[6] Total summer diet or supplement cost + yardage, health costs, land rent, and interest.
[7] Total summer cost / BW gained during the summer phase.
[8] Total diet, yardage, health, and interest costs during the finishing phase.
[9] Total finishing cost / BW gained during the finishing phase.
[10] Total of winter, summer, and finishing costs.
[11] Total costs / BW gained during the winter, summer, and finishing phases.
[12] Calculated by multiplying HCW/45.4 kg times 5-Area Market prices/45.4 kg.
[13] Total revenue – total costs.

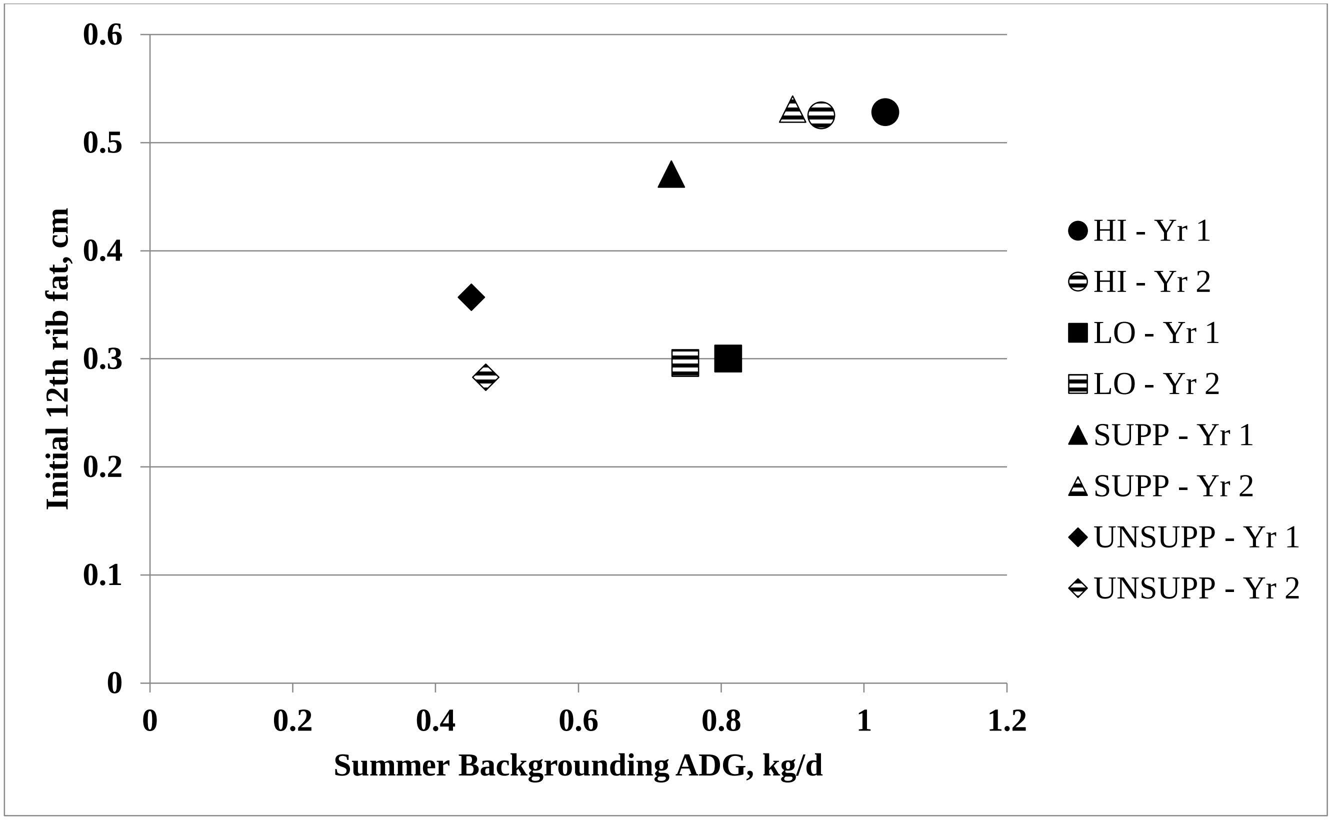

Figure 1. Relationship of summer backgrounding gain and 12th rib fat at feedlot entry. Treatments = high level of backgrounding gain in pen (HI), low level of backgrounding gain in pen (LO), supplemented with DDGS at 0.6% of BW while grazing smooth bromegrass (SUPP), grazed smooth bromegrasss with no supplement (UNSUPP).

CHAPTER IV

Effect of continuous or rotational grazing on growing steer performance and gain per hectare.[1]

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ABSTRACT

Individual animal performance and animal production per hectare were evaluated for steers grazing smooth bromegrass over 2 consecutive years. Treatments consisted of steers continuously grazing smooth bromegrass and initially stocked at either 6.82 AUM/ha (LO) or 9.88 AUM/ha (HI) or steers rotationally grazing smooth bromegrass and initially stocked at 9.88 AUM/ha. Put and take animals were added equally to all pastures to maintain similar forage residue height and led to variable stocking rates. Diet samples were collected throughout the grazing season. There was a linear day × treatment interaction ($P < 0.01$) for in vitro organic matter digestibility (IVOMD) with ROT pastures maintaining a relatively constant IVOMD as the grazing season progressed, whereas the HI and LO diet samples showed a linear decrease in digestibility. Crude protein followed a similar trend to digestibility ($P < 0.02$). However, there were no differences in ADG between treatments ($P = 0.85$). Treatment pastures stocked more intensively, regardless of grazing method, had greater calculated stocking rate (11.9 and 12.1 AUM/ha, respectively for HI and ROT) than LO pastures (10.8 AUM/ha; $P < 0.01$). Gain per hectare, however, did not differ among treatments ($P = 0.35$). Overall, although there was an increase in diet sample quality associated with rotational grazing compared to continuously grazed pastures, greater emphasis should be placed on managing an appropriate grazing intensity, rather than grazing method.

Key words: grazing, intensity, stocking method, rotational, continuous

INTRODUCTION

During the period from 2006-2011, 530,000 ha of grassland were converted to cropland in the Western Corn Belt, comprised of North Dakota, South Dakota, Minnesota, Nebraska, and Iowa (Wright and Wimberly, 2013). This conversion of land was largely due to the sustained increase in grain prices during that same period which created a greater incentive to farm the land rather than graze it. Concurrently, land cash rent in eastern Nebraska increased from an average of $28/month per cow-calf pair (equal to 1.3 AUM) in 2006 to $56.40/month per cow-calf pair in 2016 (Jansen and Wilson, 2016). Therefore, with decreased availability of grasslands for grazing and increased rent associated with grazing, optimizing use of land both in terms of animal performance and production per fixed unit of land is important to offset increases in costs associated with grazing. A commonly discussed method for optimizing use of land is through the use of rotational grazing. Rotational grazing is a stocking method that has been reported to increase stocking rates while maintaining similar individual animal gain by dividing a pasture into separate paddocks that undergo short periods of grazing followed by longer periods of rest (Briske, 2008). Multiple grazing studies have reported no difference in ADG but an increase in gain per hectare due to increased stocking rates for rotationally grazed pastures compared to continuously grazed pastures (Bertelsen et al., 1993; Pitts and Bryant, 1987; Aiken, 1998). In a review by Briske et al. (2008) evaluating research studies comparing continuous and rotational grazing, animal production per hectare was equal or greater for continuous compared to rotational grazing in 27 of 32 trials. The authors also reported that in 35 of 38 studies, individual animal gain was equal for both

grazing methods. Of note, the trials evaluated by Briske et al. (2008) were conducted on native rangelands. Positive responses to rotational grazing have been reported to be more likely on cool-season forages compared to native range and improved warm-season forages (Sollenberger et al., 2012). The objective of this study was to compare the effects of rotational grazing compared to continuous grazing, at stocking rates equal to or lesser than the rotational grazing stocking rate, on forage nutritive value, individual animal performance, and animal production per unit of land.

MATERIALS AND METHODS

One hundred and forty-two yearling steers were utilized to graze smooth bromegrass pastures over the course of two grazing seasons in 2015 and 2016, at the Eastern Nebraska Research and Extension Center (ENREC) near Mead, NE. All animals involved in this study were managed in accordance with the protocols approved by the Animal Care and Use Committee at the University of Nebraska. Three treatments were applied consisting of cattle continuously grazing bromegrass pastures at an initial stocking rate of 6.82 animal unit months (AUM)/ha (LO), 9.88 AUM/ha (HI), or cattle rotationally grazing smooth bromegrass at an initial stocking rate of 9.88 AUM/ha (ROT).

Pasture and Animal Management

Each year, 71 crossbred steer calves (313 kg, SD = 6) were assigned to 1 of 3 treatments with 3 replications per treatment. Prior to the start of the 2 years, treatments were allocated randomly to 1 of 9 pasture areas. Pastures were either 3.2 or 3.6 ha and therefore contained different numbers of cattle to meet the appropriate stocking rate.

Treatments were then maintained on the same pasture areas for both years of the experiment. For the rotationally grazed pastures each pasture area was divided into 6 paddocks that were separated by a single strand of electric fence. Paddocks were rotationally grazed for an average of 156 days each year from April to September. The grazing period was divided into 5 cycles with cycle 1 lasting 24 days and cycles 2, 3, and 4 lasting 36 days. Cattle assigned to the ROT treatment rotated paddocks every 4 d during cycle 1 and 6 d during cycles 2, 3, and 4. In all pastures, urea was surface applied as the N source at a rate of 90 kg N/ha in late March or early April, prior to the initiation of grazing. Cattle were implanted with 40 mg trenbalone acetate and 8 mg estradiol on d 1 of the trial each year (Revalor-G; Merck Animal Health, Summit, NJ).

Seven to 9 tester animals were maintained on each pasture, depending on size and treatment grazing intensity, at all times for performance measurements. A variable stocking rate was used in order to maintain a similar grazing pressure across all 3 treatments by utilizing put and take animals that were added or removed depending on forage production. Determination of forage yield was conducted visually to maintain approximately 10 cm of standing forage in the HI and ROT pastures at the conclusion of grazing. By utilizing put and take animals added equally across treatment pastures and varying stocking rate, the effects of treatment on animal performance and animal production per hectare of land were measured while maintaining similar grazing pressure across treatments. Put and take animals were not used to calculate individual performance but were used to calculate total number of head days. Number of head days for each treatment was calculated by multiplying the number of test steers by number of grazing

days plus number of put and take animals multiplied by number of grazing days on each pasture. Pastures were initially stocked each spring at a rate described above for each treatment. To calculate AUM/ha, total head days for each pasture was converted to total months, multiplied by average BW of the tester animals, expressed as animal units (454 kg), and then divided by the pasture area (ha).

Beginning and ending BW measurements were collected on 3 consecutive days (Stock et al., 1983) and averaged following 5 days of being limit fed a diet of 50% alfalfa hay and 50% Sweet Bran (Cargill Corn Milling, Blair, NE) at approximately 2% of BW to equalize gut fill (Watson et al., 2013).

Forage Measurements

Diet samples were collected once during each grazing cycle on a paddock rotation day, prior to ROT cattle being rotated. Two ruminally cannulated steers were used to sample a pasture from each treatment (6 steers total). Steers were fasted overnight and ruminally evacuated at 0800 h on each sampling day. Steers were given 30 min to graze each paddock or pasture, then brought back to the handling facility where masticate samples were collected and immediately put on ice, and rumen contents were returned to the rumen. Upon arrival at the laboratory, samples were frozen at -4ºC until being lyophilized at -50ºC (Virtis Freezemobile 25ES; Life Scientific, Inc.), and ground through a 1-mm screen using a Wiley mill (number 4; Thomas Scientific). Diet samples were analyzed for OM, NDF, CP, and in vitro organic matter digestibility (IVOMD). Ash analysis was conducted by placing samples in a muffle furnace for 6 h at 600ºC (AOAC, 1999; method 4.1.10). Neutral detergent fiber analysis was done using the method

outlined by Van Soest et al. (1991). Crude protein was analyzed using a combustion chamber (TruMac CN, Leco Corporation, St. Joseph, MI; AOAC, 1999; method 990.03) by a commercial lab (Ward Laboratories, Inc., Kearney, NE). In vitro organic matter digestibility was determined using the method outlined by Tilley and Terry (1963) with the addition of 1 g/L of urea to the McDougall buffer (Weiss, 1994). Rumen fluid was collected from 2 ruminally cannulated donor steers provided a mixed diet of 70% bromegrass hay and 30% distillers grains. Five forage standards of differing nutritive values and known in vivo OM digestibilities were used to adjust the IVOMD values to the known in vivo values (Geisert, 2007).

Estimates of forage mass were taken at the beginning and end of the grazing season each year to determine differences in mass and if appropriate grazing pressure was applied. The drop disc method was used (Sharrow, 1984; Karl and Nicholson, 1987). Twenty-five discs (0.26 m^2) were taken at random across each treatment pasture. At 5 of those disc heights, a clipping was taken from a quadrat (0.38 m^2). Disc heights were then correlated to actual forage mass from the clipping and used to estimate available forage mass in each pasture.

Statistical Analysis

Data were analyzed using the GLIMMIX procedure of SAS (SAS Institute, Inc., Cary, NC) as a generalized randomized block design (n = 3) with 1 replication per block. Model effects included year, treatment, block, and the year × treatment interaction for performance. Diet sample values were analyzed using covariate regression with Julian date as the covariate, treatment as a fixed effect, and year as a random effect.

Significance was declared at $P < 0.05$ and tendencies are discussed at $P < 0.10$. One replication of the HI treatment was removed from the analysis in each year due to poor performance of the treatment pasture, unrelated to the experiment.

RESULTS AND DISCUSSION

Forage Analysis

Monthly rainfall (Table 1) over the summers of 2015 and 2016 was 6 – 16 cm more rain than average. There was no year × treatment interaction for measures of forage nutritive value ($P > 0.15$). Forage OM tended to be higher for the HI and ROT treatments (88.3 and 88.9%, respectively) compared to the LO treatment (87.2%; $P < 0.08$); however, the small difference likely is not biologically significant. There was a tendency for a quadratic day × treatment interaction on NDF level of forage ($P = 0.07$; Table 2). Neutral detergent fiber tended to be greater for the LO treatment in mid-July compared to the HI and ROT treatments. In early-August, NDF tended to be greater for the ROT treatment compared to the LO and HI treatments. Likewise, there was a significant quadratic day × treatment interaction for CP ($P < 0.02$). At the beginning and end of the grazing season, all treatments had similar CP levels. However, during the period from early July to mid-August, when temperatures are highest and growth of cool-season grasses is least, the HI and ROT diet samples tended to have greater CP concentrations than LO diet samples. For IVOMD, there was a linear day × treatment interaction ($P < 0.01$). As time of the grazing season progressed, ROT forage maintained a relatively constant IVOMD, whereas the HI and LO diet samples decreased in a linear fashion. The

timing of diet sample can have an effect on treatment forage quality. Bertelsen et al. (1993) measured forage quality of alfalfa-tall fescue-orchardgrass pastures under continuous or one of two rotational grazing strategies (6 or 11 paddocks) pre and post grazing at differing time points during the grazing season. Pre-graze diet samples from the continuous pastures were higher in NDF and ADF and lower in CP compared to the two rotational grazing treatments. However, post grazing, continuously stocked pastures had lower levels of ADF and NDF and higher levels of CP compared to the two rotationally stocked treatments. Diet samples measuring forage nutritive value in the current study were taken pre-graze and would agree with the pre-graze results of Bertelsen et al. (1993) that rotationally grazed pastures had higher forage nutritive value at that time than continuously grazed pastures. Time of season appears to have a greater effect on forage nutritive value than stocking method. In general, for all three treatments, measures of nutritive value were greater at the beginning and end of the grazing season in May and September, and lesser in the middle of the season in July. The middle of the grazing season, when diet samples had the lowest nutritive value for all three treatments, is when cool-season grasses are experiencing the “summer slump” due to temperatures above optimal level for photosynthesis in C3 grasses (Jones, 1985). Due to the variation in research, in relation to timing of sampling relative to grazing, and method of sampling, Sollenberger et al. (2012) concluded that the effect of grazing method on forage nutritive value was inconclusive, and that ultimately, animal performance was the most accurate way to assess the relative benefits of one stocking method over another.

Cattle Performance

There were no treatment × year interactions for any performance measures ($P >$ 0.40). Ending BW and ADG did not differ among treatments ($P \geq 0.85$; Table 3). Similar individual animal gains have been widely reported for continuous and rotational grazing systems, both when continuous and rotational treatments are stocked at an equal rate (Lomas et al., 2000; Hart et al., 1993), and when rotational treatments are stocked at a higher rate than the continuous treatment (Heitschmidt et al., 1982; Pitts and Bryant, 1987; Hoveland et al., 1997; Bertelsen et al., 1993). The current study would support the findings of both levels of stocking rate. In contrast, Walton et al. (1981) reported increased ADG for steers rotationally grazing alfalfa-bromegrass-creeping red fescue pastures compared to those continuously grazing in the second 2 years of a 4-year study. This is likely due in part to the increased forage quality associated with the rotationally grazed pastures in that study, whereas forage quality was largely similar in the current study. Conversely, Volesky et al. (1990) reported increased ADG of continuously grazed calves compared to rotationally grazed calves. Increased ADG for the continuously grazed steers was explained to be a result of increased selection of species and plant parts, resulting in a diet of higher quality. Conflicting results are possibly a result of differing forage systems in the two studies. Walton et al. (1981) conducted research utilizing cool season grasses while Volesky (1990) utilized native range pastures which have greater variation in forage quality among species.

Stocking rate was greater for HI and ROT treatments compared to LO ($P < 0.01$). Calculated stocking rate for HI and ROT pastures was 11.9 and 12.1 AUM/ha, respectively, while LO was 10.8 AUM/ha. All treatments had greater actual stocking

rates over the course of the grazing season than the initial stocking rate. This is most likely due to above average rainfall in 2015 and 2016, which would result in increased forage production and therefore required more head days to maintain prescribed forage height. However, even though there was an increase in stocking rate associated with HI and ROT treatments, gain per hectare did not differ among treatments ($P = 0.35$). A possible explanation for this is the relatively small differences in actual AUM/ha between the LO and HI and ROT treatments. This combined with no differences in ADG led to a numerical increase in gain per hectare for the HI and ROT treatments compared to the LO, but due to a large standard error, was not statistically significant. In agreement with the current results showing no difference between treatments, Lomas et al. (2000) reported no differences in gain per hectare for cows and their calves grazing bermudagrass interseeded with wheat and legumes when continuously or rotationally grazing. Similarly, Pitts and Bryant (1987) reported that, when stocked at the same rate, rotationally grazed and continuously grazed treatments had similar gain per hectare. In their study, conducted over 4 years on native range in the Texas High Plains, rotationally grazed steers were stocked at 2 and 1.5 times greater than continuously grazed cattle in year 2 and years 3 and 4, respectively. When stocked at double that of continuously grazed cattle, rotationally grazed cattle had gains of 0.15 kg/d compared to 0.25 kg/d for continuous cattle. Gain per hectare was similar between treatments as the increase in stocking rate was offset by the decrease in ADG of rotationally grazed animals. When reduced to only 1.5 times greater in years 3 and 4, ADG was similar between treatments. Therefore, gain per hectare was greater for rotationally grazed pastures compared to

continuous. Increased production per unit of land as a result of similar ADG and increased stocking rate is largely supported by the literature with the caveat that this increase in gain per hectare is largely a result of the increased stocking rate and therefore grazing intensity, rather than the grazing method itself (Briske et al., 2008; Rouquette, 2015; Sollenberger et al., 2012). Sollenberger et al. (2012) evaluated the results of 29 and 26 experiments, comparing the effects of rotational and continuous grazing, on individual animal gains and gain per unit of land, respectively. Of the 29 papers comparing animal ADG, rotationally grazed cattle had increased gain in 4, continuously grazed cattle had increased gain in 6, and there were no ADG differences in 19. Likewise, when evaluating the 26 papers comparing the two grazing methods on gain per unit of land, rotational grazing yielded greater gain/hectare in 7, continuous grazing was greater in 1, and there were no differences in 19. The review from Sollenberger et al. (2012) was largely in agreement with that by Briske et al. (2008) which reported the same general findings, that stocking rate was of greater importance than grazing method. Of note, is that the 7 studies evaluated by Sollenberger et al. (2012) showing increased gain per hectare were all pastures comprised of cool-season grasses. These studies were done primarily in temperate environments with greater average rainfall than range settings. With higher rainfall, there is also increased growth of the forage and therefore possibly a benefit in keeping the plant in a vegetative state by rotational grazing. Therefore, the authors concluded that while variation in results makes a recommendation of one method over another not possible, the likelihood of observing increased gain/per hectare as a result of rotational grazing would likely be in cool-season pastures. An increase in gain/hectare

was not observed in the current experiment due to the relatively small differences in actual stocking rate between treatments even though a variable stocking rate was utilized.

There was no year × treatment interaction for estimated available forage ($P >$ 0.40). At the beginning of the grazing season, LO pastures tended to have greater forage mass (2028 kg/ha) than HI pastures (1682 kg/ha; $P = 0.07$), with ROT pastures being intermediate (1755 kg/ha; Figure 1). At the conclusion of the grazing season, there were no differences in estimated available forage mass between treatments with LO, HI, and ROT pastures having estimates of 976, 891, and 759 kg/ha, respectively. Similar estimates of forage mass at the conclusion of the grazing season would indicate that treatment pastures were managed appropriately in relation to one another to achieve a similar ending residue level at the end of the grazing season.

IMPLICATIONS

The results of this study indicate that individual animal gains are not affected by grazing method. Additionally, gain/hectare was similar between treatments even though the HI and ROT treatments had increased stocking rate, although relatively small, in comparison to the LO treatment. Advantages of rotational grazing include keeping forage in a vegetative state which affects forage quality. The increase in forage quality was observed during the summer slump period but did not translate into increased ADG or gain/ha. Although there may be benefits to rotationally grazing cool season pastures, the greatest emphasis should be focused on grazing intensity rather than grazing method.

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Table 1. Monthly rainfall at Eastern Nebraska Research and Extension Center near Mead, NE from 2007-2016

	Rainfall, cm		
Month	2015	2016	10-yr Average
March	2.0	2.5	2.4
April	9.2	12.5	9.2
May	19.8	18.7	14.3
June	15.3	10.3	15.7
July	9.0	9.5	6.9
August	19.5	14.3	12.6
September	10.2	7.5	7.8
Total	85.0	75.3	68.9

Table 2. Nutritive value of diet samples by treatment and sampling date across years

	Julian Day[1]										*P* – value				
Treatment[2]	120	134	153	157	195	218	230	259	260	SEM	Trt	Day	T*D	D*D	T*D*D
CP, % DM										1.1	0.03	0.10	< 0.01	< 0.01	0.02
LO	21.0^{b}	15.3	14.4^{b}	15.4	15.6^{b}	16.8^{ab}	16.0^{b}	23.2^{a}	17.7^{b}						
HI	19.9^{b}	17.4	15.3^{ab}	16.6	21.6^{a}	19.3^{a}	17.9^{ab}	19.2^{b}	18.5^{b}						
ROT	26.7^{a}	16.3	17.9^{a}	15.2	22.9^{a}	15.0^{b}	20.0^{a}	23.9^{a}	22.5^{a}						
NDF, % DM										3.0	0.45	< 0.01	0.77	0.01	0.07
LO	65.1	62.7	70.5^{a}	78.2	75.0^{a}	71.5^{b}	61.3	56.9	75.1^{a}						
HI	68.8	71.3	66.4^{b}	73.1	61.2^{b}	70.4^{b}	63.5	61.4	68.4^{ab}						
ROT	64.0	66.7	68.5^{ab}	71.0	67.0^{ab}	79.5^{a}	59.6	58.2	63.2^{b}						
IVOMD, % DM										2.8	0.03	< 0.01	< 0.01	0.12	0.74
LO	74.0	66.7	69.1	66.3	55.9^{b}	56.7^{ab}	61.1^{b}	68.5^{ab}	43.5^{c}						
HI	70.7	66.3	71.4	65.8	65.0^{a}	50.7^{b}	62.1^{b}	60.8^{b}	53.8^{b}						
ROT	71.1	66.5	72.1	62.0	64.4^{a}	62.3^{a}	72.4^{a}	73.2^{a}	64.6^{a}						

[abc] Means within Julian day and nutritive measurement with differing superscripts are different ($P < 0.07$).

[1] Four sampling dates in 2015 and five sampling dates in 2016.

[2] Treatments consisted of continuously grazed pastures initially stocked at 6.82 AUM/ha (LO), continuously grazed pastures initially stocked at 9.88 AUM/ha (HI), rotationally grazed pastures initially stocked at 9.88 AUM/ha (ROT).

Table 3. Effect of grazing strategy on performance of yearling steers grazing smooth bromegrass pastures

	Treatments[1]				
	LO	HI	ROT	SEM	*P* - Value
Initial BW, kg	312	313	313	0.31	0.36
Ending BW, kg	404	401	404	5.17	0.87
ADG, kg	0.59	0.56	0.58	0.03	0.85
AUM/ha[2]	10.8[b]	11.9[a]	12.1[a]	0.12	< 0.01
Gain/hectare, kg	239	256	267	15.7	0.35

[a,b,c] Means within a row with differing superscripts are different ($P < 0.05$).

[1] Treatments consisted of continuously grazed pastures initially stocked at 6.82 AUM/ha (LO), continuously grazed pastures initially stocked at 9.88 AUM/ha (HI), rotationally grazed pastures initially stocked at 9.88 AUM/ha (ROT).

[2] Actual stocking rate.

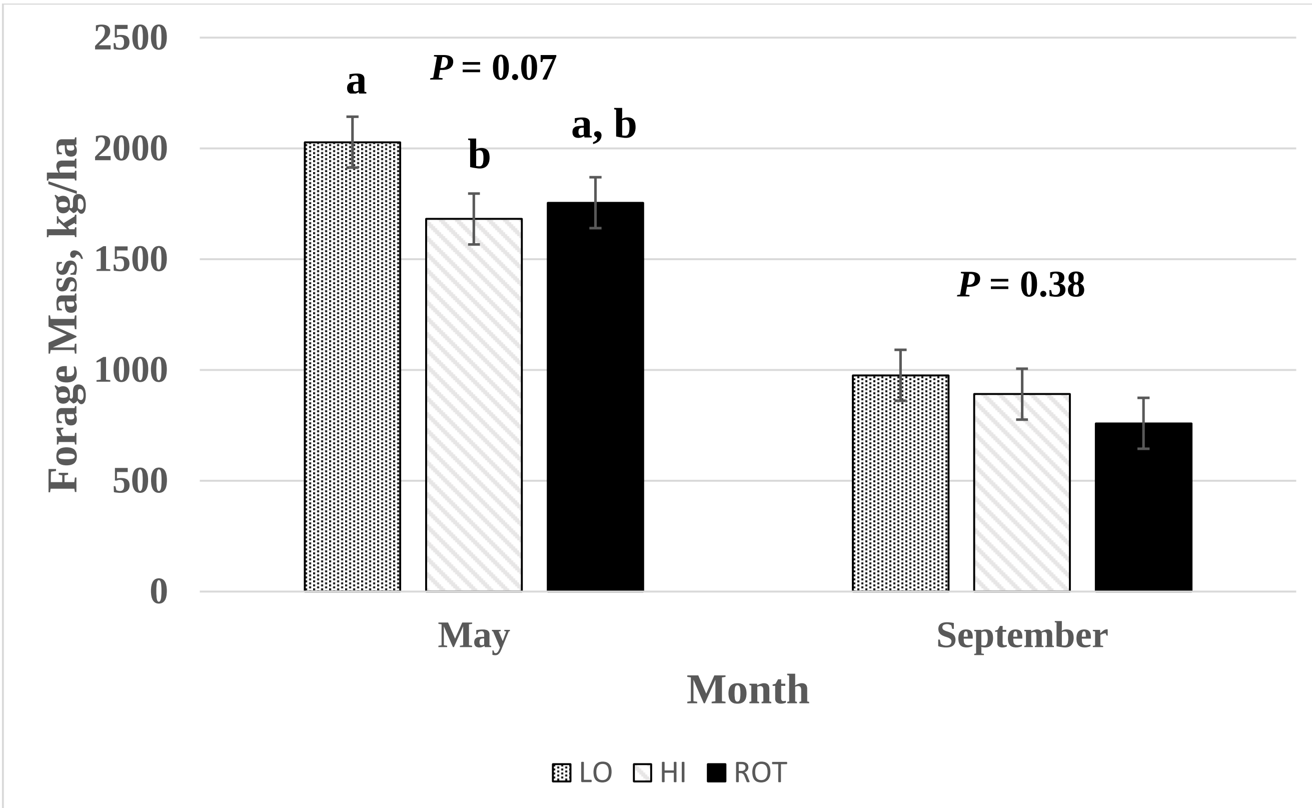

Figure 1. Estimated forage mass of smooth bromegrass pastures by treatment and sampling date across two years. Treatments consisted of continuously grazed pastures initially stocked at 6.82 AUM/ha (LO), continuously grazed pastures initially stocked at 9.88 AUM/ha (HI), rotationally grazed pastures initially stocked at 9.88 AUM/ha (ROT).

CHAPTER V

Effect of pelleted byproducts on performance when supplemented to growing cattle.[1]

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ABSTRACT

Three studies were conducted to evaluate the effects of supplementing cattle consuming forage diets with pellets containing CaO-treated corn stover and dry milling byproducts on animal performance. Experiment 1 utilized 300 heifers (initial BW 279 kg, SD = 22) in a 2 × 3 factorial design with forage quality, low (LQ) or high (HQ), as one factor, and rate of supplementation as the second (0, 0.5, or 1.0% of BW). The pellet contained 53% CaO-treated corn stover, 32% dried distillers grains, 14% solubles, and 1% urea. A forage × supplement interaction existed for ending BW, ADG, and G:F ($P <$ 0.01). For the HQ forage diet there was a linear increase in BW, ADG, and G:F as supplement level increased ($P < 0.01$), while for the LQ forage diet there was a quadratic response ($P \leq 0.03$) as supplement level increased. Experiments 2 and 3 were corn residue grazing trials arranged as 2 × 3 factorials, in which inclusion of bambermycins (0 or 10 mg/d and 0 or 20 mg/d for Exp. 2 and 3, respectively) was the first factor. The second factor was supplementation rate (Exp. 2) and amount of RUP supplied in the pellet (Exp. 3). Experiment 2 utilized 60 individually fed steers (initial BW = 254 kg; SD = 26), supplemented a pellet consisting of 54% CaO-treated corn stover, 32% dried distillers grains, and 14% solubles at 0.3, 0.7, or 1.1% of BW. Experiment 3 utilized 60 individually fed steers (initial BW = 222 kg; SD = 14) supplemented with a pellet consisting of 44.5% CaO-treated corn stover, 40% Soypass, soybean meal (SBM), or processed SBM, and 15.5% solubles at 1.82 kg/d. In Exp. 2, steers were dosed with 10 g of TiO_2 daily to measure residue intake. There was no bambermycins × supplement level interaction on ending BW, ADG, or DMI in Exp.2 ($P \geq 0.82$). Bambermycins inclusion

did not affect ending BW, ADG, or DMI ($P \geq 0.75$). There was a linear increase ($P < 0.01$) for ending BW and ADG as pellet supplementation increased. For steers supplemented at 0.3, 0.7 and 1.1% of BW, ADG was -0.01, 0.28 and 0.56 kg/d, respectively. There was a quadratic decrease in DMI as the trial progressed and supplement increased ($P < 0.01$). In Exp. 3, there was no bambermycins × RUP supplied interaction for ending BW or ADG ($P \geq 0.61$). Bambermycins inclusion at 20 mg/steer daily did not affect ending BW or ADG ($P \geq 0.79$). Likewise, there was no main effect of pellet type on ending BW or ADG ($P \geq 0.57$). The pellets supplemented in Exp. 1 and 2 increased performance as supplementation rate increased.

Key words: alkaline treatment, corn residue, forages, supplementation, grazing, pelleted feed

INTRODUCTION

As a result of increased grain prices, from the period of 2006-2011 there was a large amount of grassland converted to cropland in the western Corn Belt, which has resulted in widespread availability of corn residues through much of the Midwest region (Watson et al., 2015). Corn residue is typically thought of as low quality forage, due to the variability in nutrient composition of the various plant parts, chemically treating with calcium oxide (**CaO**) increases the digestibility of the residue (Shreck et al., 2015b); additionally, decreasing particle size of the residue prior to treatment further increases digestibility (Shreck et al., 2015a). Concurrently, the use of distillers grains (**DGS**) has become commonplace in all segments of beef production. Supplementation of distillers grains to cattle consuming low quality forage such as corn residue and grass hay supplies

a source of rumen undegradeable protein (**RUP**) and has been reported to increase gain (Ahern et al., 2016; Jones et al., 2014; Morris et al., 2005). Feed additives, such as ionophores, are also an option for increasing ADG of cattle grazing forage (Bretschneider et al., 2008). Bambermycins (Gainpro; Huvepharma Inc, Sofia, Bulgaria) is an antimicrobial feed additive that has been reported to increase ADG in forage diets (Beck et al., 2016). Novel processes have been developed to combine CaO treated residue with DGS and condensed distillers solubles into a pellet. Gramkow et al. (2016a) reported increases in gain for calves fed a pellet containing CaO treated corn residue, DGS, and solubles when fed ad libitum, compared to a control diet comprised of the same ingredients with the only difference being that the corn residue included wasn't alkaline treated and the complete diet wasn't pelleted. The objective of these trials was to evaluate the effects of supplementation with a novel pellet containing CaO treated residue and bambermycins on the performance of growing cattle consuming forage diets.

MATERIALS AND METHODS

All animal care and management procedures were approved by the University of Nebraska-Lincoln Institutional Animal Care and Use Committee.

Experiment 1

An 84-d growing trial was conducted utilizing 300 heifers (initial BW = 279 kg; SD = 22) in a 2 × 3 factorial design. The first factor was forage quality with low quality (**LQ**) or high quality (**HQ**) forage as the basal diet. The LQ diet consisted of bromegrass hay and the HQ diet was comprised of 50% bromegrass silage, 37.5% alfalfa hay, and 12.5% sorghum silage. The second factor was increasing rates of pellet supplementation

at 0, 0.5, or 1.0% of BW. The pellet consisted of 53% CaO-treated corn stover, 32% dried distillers grains, 14% solubles, and 1% urea (provided by Pellet Technology, USA Gretna, Neb.). Pellets were produced prior to the initiation of the experiment to minimize any potential load variation. Pellets were produced by grinding corn stover to a small particle size (297-1,680 µm). Corn distillers solubles was added to hydrate the corn stover to 50% DM. As solubles was added, CaO was added simultaneously (5% of the forage DM). The mixture then went through an extruder (66-121ºC) to increase the rate of the chemical reaction. After the extrusion process, the mixture was mixed with DDGS and urea and pelleted (Zeeck, 2013).

Initial processing when calves were received in the feedlot included vaccination for protection against infectious bovine rhinotracheitis caused by infectious bovine rhinotracheitis virus, bovine viral diarrhea caused by bovine virus diarrhea virus Types 1 and 2, and disease caused by parainfluenza3 virus and bovine respiratory syncytial virus (Bovi-Shield Gold 5; Zoetis, Florham Park, New Jersey), control against gastrointestinal roundworms, lungworms, eyeworms, grubs, sucking lice, and mange mites; (Dectomax injectable; Zoetis) and prevention of blackleg caused by *Clostridium chauvoei*, malignant edema caused by *Clostridium septicum*, black disease caused by *Clostridium novyi*, gas-gangrene caused by *Clostridium sordellii*, enterotoxemia and enteritis caused by *Clostridium perfringens* Types B, C and D, and disease caused by *Histophilus somni* (*Haemophilus somnus;* Ultrabac 7; Zoetis). All heifers were limit fed a diet consisting of 50% alfalfa and 50% Sweet Bran (Cargill Wet Milling, Blair, NE) at 2.0% of BW for 5 days to equalize gut fill (Watson et al., 2013). Heifers were weighed on 2 consecutive

days (d 0 and 1) and the average of those 2 days was used as initial BW (Stock et al., 1983). Heifers were blocked by BW (n = 3) and stratified by BW within block and assigned randomly to pens using the d 0 weights. Treatments (n = 6) were assigned randomly to pens with 5 replications per treatment, and 10 heifers per pen. The first weight block had 1 replication, the second weight block had 3 replications, and the third weight block had 1 replication. Pen was the experimental unit. Heifers were dosed with gamma-cyhalothrin for control of horn flies and lice (StandGuard; Elanco Animal Health, Indianapolis, IN) and implanted with 36 mg of zeranol (Ralgro; Merck Animal Health, Summit, NJ) on d 1. Heifers were fed basal forage ad libitum. Feed bunks were observed daily at 0600 hr and amount of forage delivered was managed so that at 0800 hr minimal hay remained. At 0700 hr supplemental pellet was delivered followed by forage at 0800 hr. Pellet was delivered first to ensure that all supplemental pellet was consumed. Heifers had free choice access to a mineral block in the feed bunk of each pen that contained 18.5% calcium, 6% phosphorus, 27% salt, 0.6% magnesium, 0.25% potassium, 45 ppm iodine, and 750 ppm zinc (Feedlot Mineral Block; Golden Sun Feeds, St. Louis, MO).

The NRC (1996) net energy equations were used to estimate initial forage intake and pens were fed ad libitum forage thereafter. Initial BW was used to calculate initial supplement amount and adjusted on d 28 and d 56 using the NRC estimate of gain given actual forage and supplement intake. To accurately predict gain of calves consuming high-forage diets, it is imperative to utilize NE adjusters (Patterson et al., 2000; Block et al., 2006). Therefore, NE adjusters were calculated for each treatment by utilizing data reported by Morris et al. (2005), in which DGS was fed to calves consuming either high

or low quality forage at increasing levels as a % of BW on a DM-basis. For each treatment, initial forage and supplement intake were entered in the NRC model and NE adjusters were manipulated until predicted ADG matched that of Morris et al. (2005) for the appropriate forage quality and supplement level. Actual supplement intake for the low quality forage was 0.50 and 1.01% of BW, for the 0.50 and 1.00% of BW treatments, respectively. Actual supplement intake for the high quality forage was 0.49 and 0.99% of BW, for the 0.50 and 1.00% of BW treatments, respectively. Ending BW was determined similarly to initial BW. Heifers were limit fed a 50% alfalfa, 50% Sweet Bran diet for 5 consecutive days and weighed 2 days thereafter. Ending BW was then calculated by averaging the 2-d weights.

Individual feed ingredients were analyzed for OM, CP, NDF, and in vitro organic matter digestibility (IVOMD) to determine dietary nutrient composition (Tables 2, 3). Ash analysis was conducted by placing samples in a muffle furnace for 6 h at 600ºC (AOAC, 1999; method 4.1.10). Neutral detergent fiber was analyzed using the method outlined by Van Soest et al. (1991) with the addition of 0.5 g of sodium sulfite (crystalline, 98.6% assay, Fisher Scientific, Pittsburgh, PA; Buckner et al., 2013a). Crude protein was analyzed with a combustion chamber (TruSpec N Determinator; Leco Corporation, St. Joseph, MO; AOAC, 1999; Method 990.03). In vitro organic matter digestibility was determined using the method outlined by Tilley and Terry (1963) with the addition of 1 g/L of urea to the McDougall buffer (Weiss, 1994). Rumen fluid was collected from 2 ruminally cannulated donor steers provided a mixed diet of 70% bromegrass hay and 30% distillers grains. Five forage standards of differing nutritive

values and known in vivo OM digestibilities were used to adjust the IVOMD values to the known in vivo values (Geisert, 2007).

Performance (BW, ADG, G:F) and intake (forage DMI and total DMI) data were analyzed as a 2 × 3 factorial using the GLIMMIX procedure of SAS (SAS Institute, Inc., Cary, N.C.) with pen as the experimental unit. The model included forage quality, supplement level, forage quality × supplement level interaction, and block as fixed effects. Six heifers were removed from the study due to respiratory or locomotion issues. Initial BW was used in the model as a covariate due to a 2 kg difference that was statistically significant for the LQ treatment but was non-significant as a covariate, and removed from subsequent analysis. Significance was declared at $P < 0.05$ and tendencies are discussed at $P < 0.10$.

Experiment 2

An 85-d corn residue grazing trial was conducted from November 5, 2014 to January 28, 2015 utilizing 60 crossbred steers (initial BW=254 kg; SD = 26). The experiment was conducted as a 2 × 3 factorial design. The first factor was inclusion of bambermycins (Gainpro) fed at either 0 or 10 mg/steer daily. The second factor was increasing amounts of pellet supplement at 0.3, 0.7, or 1.1% of BW. The primary pellet contained 18.7% CP and consisted of 54% corn stover treated with calcium oxide, 32% dried distillers grains, and 14% solubles (provided by Pellet Technology, USA, Gretna, Neb.). A second pellet was produced identically to the primary pellet with the exception that a vitamin/mineral/additive mix was included at 10% of the second pellets total DM to provide supplemental vitamins, minerals, and, depending on treatment, bambermycins.

This pellet was fed at 0.454 kg of DM/steer daily with the remaining amount of supplement provided by the primary pellet. The pellets in this study were produced using the same procedure as outlined in Exp. 1 with the exception that no urea was added.

Upon being received, steers were processed and weighed in the same manner as outlined in Exp. 1. Following weighing, steers were blocked by BW (n = 10) and assigned randomly to treatments. Steers were gathered daily at 1130 and individually offered supplement via Calan gates (American Calan, Inc., Northwood, NH) for approximately 1 hr. Following supplement consumption steers were returned to graze dryland corn residue. All steers were implanted with 36 mg of zeranol (Ralgro; Merck Animal Health, Summit, NJ) on d 1 of the experiment.

Stocking rate was calculated using estimates of residue amount and grazing efficiency as reported from previous research (McGee et al., 2012). Corn grain yield (5136 kg/0.4 ha), estimated forage availability (3.6 kg residue/25.4 kg of corn), and total area (17 ha) were multiplied to determine an estimate of total available forage for the corn field. Estimated available forage was divided by estimated DMI (4.54 kg/steer daily) to determine the number of grazing days the field could support. Supplement amount was adjusted on d 28 and 56 by taking BW measurements at 0700 and shrinking them 4% to determine interim BW. Supplement refusals were collected weekly, dried, and weighed, and subtracted from total supplement amount to calculate actual supplement consumed as a percent of BW. Actual supplement delivered did not differ from planned supplement amount.

To determine the effects of supplementation rate and bambermycins inclusion on forage intake, steers were dosed with titanium dioxide (TiO_2) at 3 separate times throughout the trial. Steers were dosed with 10 g of TiO_2 daily for 7 d prior to collecting fecal samples at 0700 on 3 consecutive days (Titgemeyer et al., 2001). Titanium dioxide was delivered via condensed distillers solubles. Prior to each dosing period, 3 kg of marker was mixed with 34.10 kg of solubles in order to supply 10 g of TiO_2/100 mL of mixture. A 100-mL dose was top dressed on each steers daily supplement during the dosing period. Fecal grab samples were composited by sampling period and dried in a 60ºC forced air oven for 48 hr. Following drying, fecal samples were ground through a 1-mm screen using a Wiley mill (number 4; Thomas Scientific) and analyzed via the wet ash procedure developed by Myers et al. (2004) for analysis of TiO_2. Fecal OM contribution from the pellet was determined by subtracting the IVOMD of the pellet from 1 and then multiplying by pellet DMI. Forage intake was then calculated by dividing total fecal OM minus fecal OM from the pellet by 1 minus the IVOMD of the diet sample.

Diet digestibility of each treatment was determined by the use of diet samples taken with 3 ruminally cannulated steers. Cannulated steers were fed in a Latin square design so that each steer represented the 0.3, 0.7, and 1.1% supplementation rates at 1 of the 3 sampling dates. Digestibility estimates for each treatment within a sampling period came from the cannulated steer consuming the specific treatment diet at that sampling date. Steers were fasted overnight and ruminally evacuated at 0800 h on each sampling day which occurred on the last day of fecal collections for that sampling period. Steers were given 30 min to graze the corn field, then brought back to the handling facility

where masticate samples were collected and immediately put on ice, and rumen contents were returned to the rumen. Upon arrival at the laboratory, samples were frozen at -4ºC until being lyophilized at -50ºC (Virtis Freezemobile 25ES; Life Scientific, Inc.), and ground through a 1-mm screen using a Wiley mill (number 4; Thomas Scientific). Diet and pellet samples were analyzed for OM, NDF, CP, and IVOMD in the same manner as explained in Exp. 1. All diet samples were analyzed in a single IVOMD run with 3 tubes per sample. Diet samples were not statistically analyzed and only used as a descriptor of forage and pellet nutritive value.

Ending BW was determined similarly to initial BW. Performance (BW and ADG) data were analyzed using the GLIMMIX procedure of SAS (SAS Institute, Inc., Cary, N.C.) with steer as the experimental unit. The model included bambermycins inclusion, supplementation rate, bambermycins × supplementation rate interaction, and block as fixed effects. Intake data were analyzed using the MIXED procedure of SAS with sampling date and supplementation rate included in the model statement. One steer was removed from the 0.7% with bambermycins inclusion treatment due to chronic bloating. Significance was declared at $P < 0.05$ and tendencies are discussed at $P < 0.10$.

Experiment 3

An 84-d corn residue grazing trial was conducted from November 10, 2015 to February 1, 2016. Sixty crossbred steers (initial BW = 222 kg; SD = 14) were evaluated in a 2 × 3 factorial treatment design. The first factor was inclusion of bambermycins (Gainpro) fed at either 0 or 20 mg / steer daily. Bambermycins was included in a common soyhull-based supplement that was formulated to provide supplemental vitamins

and minerals and fed at 0.454 kg DM/d. Cattle not assigned to the bambermycins treatment received the same pellet at 0.454 kg DM/d with the exception that bambermycins was not included. The second factor was amount of RUP provided in the pellet when fed at 1.82 kg DM/d. Soypass (SP), soybean meal (SBM), or SBM that was further processed by Pellet Technology (PT) utilizing a heat treatment to increase the RUP content were included in the pellet at 40% of pellet DM with the remainder consisting of 44.5% corn stover treated with calcium oxide, and 15.5% solubles (provided by Pellet Technology). The SBM pellet was formulated to contain 7.5% RUP (as a % of DM) and provide 136 g of RUP/d. Both the Soypass and further processed SBM pellets were formulated to contain 15.3% RUP (as a % of DM) and provide 278 g of RUP/d. Crude protein for all 3 pellets was formulated to be 26% and pellets were produced using the same procedure as outlined in Exp. 1. All cattle were individually supplemented daily with the treatment pellet and supplement. Steers were received, limit-fed, weighed, and assigned to treatment in the same manner as Exp. 2. Steers were allowed continuous access to daily supplement via Calan gates (American Calan Inc.) and grazed irrigated corn residue. All steers were implanted with 36 mg of zeranol (Ralgro; Merck Animal Health) on d 1 of the experiment.

Stocking rate and estimates of corn residue quality were determined as in Exp. 2, with the exception that 6 ruminally cannulated steers were used for diet sampling rather than 3. Cannulated steers were supplemented with 2.27 kg/steer daily of the SBM pellet. All diet samples were analyzed in a single IVOMD run with 3 tubes per sample. Diet

samples were not statistically analyzed and only used as a descriptor of forage nutritive value.

Ending BW was determined similarly to initial BW. Steers were limit fed a 50% alfalfa and 50% Sweet Bran diet at 2% of BW for 6 consecutive days and weighed 3 consecutive days thereafter. Ending BW was calculated by averaging the 3 day weights.

Rumen degradeable protein (RDP) and metabolizable protein (MP) balances were calculated using the NRC (1996) model with actual forage and supplement intakes from Exp. 1 and Exp. 2. For Exp. 3, the slope of the intake line as supplementation rate increased from 0.7 to 1.1% of BW in Exp. 2 was used to estimate forage intake while actual supplement intake was used. Microbial efficiency was calculated for each treatment using the equation from Patterson et al. (2006). Crude protein of the forages in Exp. 1 were adjusted to account for total tract indigestible protein (Buckner et al., 2013b) and TDN of the pellet in Exp. 1 and 2 and was adjusted to 60% TDN to account for the low rumen digestible organic matter of distillers grains (Castillo-Lopez et al., 2013). Gas production data reported by Gramkow (2016) for a similar pellet also supports the adjustment of the TDN of the pellet to account for lower rumen digestible organic matter.

Performance (BW and ADG) data were analyzed using the GLIMMIX procedure of SAS (SAS Institute, Inc., Cary, N.C.) with steer as the experimental unit. Effects of Gainpro and RUP source were analyzed for interaction and main effects. Significance was declared at $P < 0.05$ and tendencies are discussed at $P < 0.10$.

RESULTS AND DISCUSSION

Experiment 1

A forage × supplement interaction existed for ending BW, ADG, and G:F (*P* < 0.01; Table 4). For the HQ forage diet, a linear increase in ending BW, ADG and G:F was observed as supplement level increased (*P* < 0.01). For the LQ forage diet, there was a quadratic response (*P* ≤ 0.03) for ending BW, ADG, and G:F as supplement level increased with ending BW, ADG, and G:F increasing at a decreasing rate. In the LQ diet, as supplement level increased from 0 to 0.5% there was a 0.29 kg increase in ADG and a 76% (0.031 kg/kg) increase in feed efficiency. As supplement increased from 0.5 to 1.0%, ADG and G:F only increased by 0.13 kg and 15%, respectively. The ADG and G:F response between 0.5 and 1.0% in LQ forage was similar to relative changes in HQ diet between 0.5 and 1.0% levels of supplementation (0.15 kg and 0.005 increase for ADG and G:F, respectively). Morris et al. (2005) reported a linear increase in ADG of calves supplemented with DGS at 0, 0.23, 0.44, 0.64, and 0.84% of BW while consuming ad libitum forage diets that were similar in quality to the diets used in the current study. The difference in ADG response for calves consuming LQ forage in the current study and the experiment by Morris et al. (2005) could be a result of greater intakes of LQ forage than observed by Morris et al. (2005). The authors reported an increase in ADG of 0.36 kg/d, both when supplement increased from 0 to 0.44% of BW and when supplement increased from 0.44 to 0.84% of BW. This increase is greater than that observed in the current study when pellet supplementation increased from 0 to 0.5% of BW. The pellets fed in the current study may have had less energy and protein compared to DGS. Corrigan et al. (2009) fed increasing amounts of DGS containing differing proportions of solubles to calves consuming the same forage diet as the high quality diet (60% alfalfa and 40%

sorghum silage) in Morris et al. (2005). Similar to heifers consuming HQ forage in the current study, there was a linear increase in ADG as distillers containing 14.5% solubles supplementation increased from 0.25 to 1.0%. Average daily gains for steers in the study by Morris et al. (2005) were 1.29 and 1.41 kg/d when supplemented at 0.50 and 1.0% of BW, respectively. Calves supplemented the same amounts in the current study gained 0.84 and 0.99 kg/d, respectively. The difference in gain between the two studies is likely due to differences in protein and energy of the supplements used.

Retrospectively, the levels of RDP and MP were analyzed using the NRC (1996) model with modifications discussed previously. The LQ control diet was deficient in RDP (-26 g/d) while the HQ control diet did not have the deficiency for RDP (+ 420 g/d). Additionally, the MP balance in the LQ control diet was -87 g/d and therefore could not be recycled as urea to make up for the RDP deficiency. As supplementation rate increased to 0.5% of BW, the LQ diet was no longer deficient in RDP. The larger increase in ADG with the LQ diet from 0 to 0.5% of BW supplementation would suggest a response to supplementing RDP, while the rate of increase from 0.5 to 1.0% of BW is similar to the response observed in the HQ forage diets, suggesting an energy response as supplement level increased from 0.5 to 1.0% of BW. Forage DMI and total DMI had linear responses as supplement increased, with forage DMI decreasing and total DMI increasing ($P < 0.01$). However, forage quality did not affect either forage or total DMI ($P \geq 0.35$). Moore et al. (1999) compiled a database to describe and estimate the effects of supplementation in forage diets. The authors reported that when the TDN:CP ratio was less than 7, that, in general, voluntary forage intake decreased with increasing rate of

supplementation. At ratios greater than 7, suggesting that there was a N deficit relative to available energy, voluntary forage intake could be increased by protein supplementation. The TDN:CP ratios for the LQ and HQ diets were 7.4 and 4.3, respectively, suggesting that protein was adequate in the HQ diet and slightly limiting in the LQ diet. A possible reason for not observing a difference in intake between the LQ and HQ diets might be that the LQ diet TDN:CP ratio was close to the threshold of 7, suggesting that N may have been limiting relative to energy. Corrigan et al. (2009) reported similar intakes to those observed in the current study. Therefore, the differences in G:F between the two studies would be a result of decreased gain when calves consumed similar amounts of forage and supplement. For the LQ treatments in this study, that is due to steers consuming a lower quality basal forage compared the diet fed by Corrigan et al. (2009) and a lower quality supplement compared to distillers grains. For the HQ treatments, it would be largely due to differences in the supplements fed (pellet vs. distillers grains). Loy et al. (2007) reported a replacement rate of 55% for higher quality forages and MacDonald et al. (2007) reported a replacement rate up to 50% of grazed bromegrass forage. Replacement rate of forage for pellet in this study was 58 and 54% for the LQ and HQ diets suggesting that supplementation with the pellet could increase stocking rate of grazing cattle.

Experiment 2

There was no interaction between inclusion of bambermycins and pellet supplementation for ending BW, ADG, or residue intake ($P \geq 0.82$). There was no main effect of bambermycins inclusion on ending BW, ADG, or forage intake ($P \geq 0.78$; Table

5) when fed at 10 mg/steer daily. In agreement with these results, Galyen et al. (2015) reported no differences in gain of calves grazing wheat when offered a free choice mineral containing bambermycins compared to a control mineral. Hubbell et al. (2000) also reported no differences in gain for calves supplemented with 20 mg/steer daily of bambermycins compared to a control when grazing endophyte infected tall fescue. In contrast, positive responses to bambermycins have been observed by Rush et al. (1996) and Beck et al. (2016). Beck et al. (2016) reported a 10% increase in ADG for heifers fed 15 mg/d of bambermycins compared to a control while Rush et al. (1996) reported a 22% increase in ADG for calves fed bambermycins. It is unclear why there was no response to bambermycins supplementation in the current study. Bretschneider et al. (2008) reported that antibiotic growth promoters such as bambermycins led to a greater response in ADG in low quality forage diets. However, the basal diet consumed by steers in the current study was likely lower in quality than the diets consumed in the studies by Beck et al. (2016) and Rush et al. (1996).

There was a linear increase ($P > 0.01$) for ending BW and ADG as pellet supplementation increased (Table 6). For steers receiving supplement at 0.3% of BW, ADG was essentially 0 (-0.01 kg/d) which resulted in an ending BW that was 1 kg less than the initial BW. For steers supplemented at 0.7 and 1.1% of BW, ADG was 0.28 and 0.56 kg/d, respectively. The lack of BW change in steers supplemented with pellet at 0.3% of BW would indicate steers were being fed at maintenance requirements. This result was unexpected based on results from Exp. 1 and would suggest that calves were significantly deficient in protein and/or energy. As supplementation rate increased,

residue intake responded in a quadratic fashion (*P* < 0.01; Figure 1). When supplemented at 0.3% of BW, residue intake was 5.71 kg/d. As supplementation increased, residue intake decreased but was not different between 0.7 and 1.1% supplementation levels (5.07 and 4.63 kg/d, respectively). In agreement with the current study, Jones et al. (2015) reported a linear increase in ADG when calves grazing corn residue were supplemented with DGS at 0.3, 0.5, 0.7, 0.9, and 1.1% of BW. However, Jones et al. (2014) and Gustad et al. (2006) reported quadratic increases in ADG as rate of supplementation increased. The likely cause for a quadratic response for ADG as supplementation rate increased in the Gustad et al. (2006) study is due to feeding DGS at levels up to 1.27% of BW. At that level, ADG increased at a decreasing rate. Jones et al. (2014) also reported that when supplemented at 1.1% of BW, there were some refusals of supplement, suggesting that a practical level of supplementation was no greater than 1.1% of BW. Gustad et al. (2006) reported that forage DMI decreased linearly as supplementation rate increased. Forage DMI in the study by Gustad et al. (2006) was similar to forage intake in the current study when supplemented with an equivalent rate of supplement. However, ADG reported by Jones et al. (2014, 2015) and Gustad et al. (2006) were greater than gains observed in this study when supplementation rates were similar. When analyzing the diets fed in this study for RDP and MP balances using the NRC (1996) model, all three treatments provided sufficient levels of RDP and MP with calves supplemented at 0.3% of BW having an RDP balance of 11 g/d, calves supplemented at 0.7% having an RDP balance of 58 g/d, and calves supplemented at

1.1% having an RDP balance of 105 g/d. Metabolizable protein balances were 144, 134, and 137 g/d for the 0.3, 0.7, and 1.1% supplementation rates, respectively.

Sampling date had a significant effect on residue intake ($P < 0.01$; Figure 2). As the grazing season progressed, residue intake decreased in a quadratic fashion. Intake in mid-November was 6.81 kg/d and decreased to 4.04 kg/d in mid-December and 4.54 kg/d in mid-January. Intake in January was greater than December ($P < 0.04$). Fernandez-Rivera et al. (1989) also reported a reduction in corn residue intake as grazing progressed. This is attributable to the fact that as grazing progresses, available forage decreases, as no new forage is being produced. Furthermore, as grazing progressed, IVOMD of diet samples decreased, which would increase rumen retention and therefore limit intake. Jones et al. (2015), Jones et al. (2014), and Fernandez-Rivera et al. (1989) all reported similar declines in digestibiltiy of residue as grazing progressed. This is a result of the animals selecting the more highly digestible parts of the corn plant at the beginning of grazing and therefore at the end of the grazing period there are less digestible plant parts available for the animal to consume. Residue intake in the current study was less than reported by Fernandez-Rivera et al. (1989) for steers of a similar weight. This is likely due to the increased rate of supplementation, leading to a substitution effect in the current study. The decrease in residue intake observed in the current study as grazing season progressed is largely influenced by the decrease in IVOMD of the residue.

Experiment 3

There was no interaction between inclusion of bambermycins and pellet type for ending BW or ADG ($P \geq 0.61$). Similar to Exp. 2, inclusion of bambermycins in the

pellet had no effect on ending BW or ADG of steers when fed at 20 mg/steer daily ($P >$ 0.79; Table 7). Likewise, there was no main effect of pellet type on ending BW or ADG ($P \geq 0.57$; Table 8). For steers receiving the pellet with supplemental protein provided by SBM, ADG was 0.35 kg/d while steers fed a pellet with supplemental protein provided from either Soypass or further processed SBM gained 0.33 and 0.35 kg/d, respectively. Fernandez-Rivera et al. (1989) reported that as RUP increased in a supplement provided at 0.83 kg/d DM (0.31% of BW) to steers grazing corn residue, so too did ADG. This occurred up to 163 g of supplemental RUP provided within approximately 400 g of CP. Gains plateaued when RUP provided exceeded 163g/d. Average daily gains at the lowest levels of RUP were 0.12 kg/d and 0.31 kg/d at the highest levels. Amount of CP and RUP provided in the supplement in that study ranged from 200 to 450 g/d and 33 to 256 g/d, respectively. Likewise, Tomlinson et al. (1997) reported that ADG of Holstein heifers increased linearly as RUP increased in the diet. The authors suggested that the increased gain was possibly attributable to the increased flow of amino acids to the small intestine, related to the increase in RUP percentage, and improved absorption and composition of those amino acids. Furthermore, protein in the form of RUP that is in excess of MP requirements can be deaminated and enter the TCA cycle as an energy source, possibly contributing to excess gain. In studies where increased levels of RUP did not lead to increases in ADG, a possible explanation is that protein was overfed, which may have lessened the response to increasing RUP amounts (Swartz et al., 1991). In the current study, it is likely that RDP and MP balances of the treatments influenced gain. Although all 3 treatments were formulated to provide an additional 473 g/d of CP to the animal,

actual amount of supplemental protein varied from 462 to 500 g/d due to differences in CP of the pellets. However, treatment supplements were not formulated to meet RDP requirements of the animal, regardless of RUP level of the pellet. Therefore, MP balance was greater for the soybean meal heat processed by Pellet Technology and SoyPass treatments (251 and 238 g/d, respectively) compared to the SBM treatment (124 g/d), even after taking into account MP needed to meet RDP deficiencies. Excess MP, however, did not increase performance, further suggesting that energy was the limiting nutrient.

Supplementation with the pelleted product resulted in increased gains for cattle consuming forage diets of differing quality. Increased gain response observed in cattle consuming a low quality forage diet is likely due to a protein supplementation response compared to an energy response for cattle consuming the higher quality diet. Likewise, in Exp. 2, as supplementation with the pelleted product increased, ADG linearly increased. The difference in ADG observed in Exp. 1 and Exp. 2 when pellet was supplemented at similar rates can be partially explained by differences in forage intake, along with TDN differences of the base forage diets. Additionally, the pellet fed in Exp. 2 and 3 did not contain urea whereas the pellet fed in Exp. 1 did. This, however, likely did not affect performance because of recycling. It was hypothesized that by increasing the amount of RUP provided by the pellet would increase ADG of steers grazing corn residue. However, ADG in Exp. 3 was less than that observed in Exp. 2 at a similar supplementation rate. This may be a result of decreased TDN provided by the pellet due to reformulation to provide differing amounts of RUP. Additionally, residue quality was

lesser in Exp. 3 than in Exp. 2 which has been previously reported for irrigated corn residue compared to dryland corn residue (Fernandez-Rivera and Klopfenstein, 1989). Furthermore, response to increased RUP levels was likely masked by similar MP balances, once RDP requirements were accounted for.

Overall, supplementation with the pelleted product led to increased gains when fed at increasing rates. However, an increase in ADG due to increasing RUP levels was not observed. The pelleted product, as formulated in Exp. 1 and 2 could be a viable option to supplement grazing cattle with, depending on price relative to other feeds.

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Table 1. Exp. 2 and 3 supplement composition fed at 0.454 kg/d (DM-basis)

	Exp. 2		Exp. 3	
Ingredient, % DM	Gainpro[1]	No Gainpro[1]	Gainpro[1]	No Gainpro[1]
Fine ground corn	91.85	93.85	-	-
Soybean hulls	-	-	91.55	93.85
Tallow	2.50	2.50	2.50	2.50
Salt	3.00	3.00	3.00	3.00
Beef trace minerals[2]	0.50	0.50	0.50	0.50
Vitamin A-D-E[3]	0.15	0.15	0.15	0.15
Gainpro[4]	2.00	-	2.30	-

[1] Formulated to deliver 10 mg bambermycins/steer daily in Exp. 2 and 20 mg bambermycins/steer daily in Exp. 3.
[2] Premix contained 10% Mg, 6% Zn, 4.5% Fe, 2% Mn, 0.05% Cu, 0.3% I, and 0.05% Co.
[3] Premix contained 1,500 IU of vit A, 3,000 IU of vit D, and 3.7 IU of vit E per gram.
[4] Contained 22 g of bambermycins per kg of Gainpro

Table 2. Nutrient composition of pellet in Exp. 1, 2, and 3

	Exp. 1[1]	Exp. 2[2]	Exp. 3[3]		
Nutrient			SBM[4]	PT[4]	SP[4]
DM, %	85.0	95.4	84.5	87.3	85.6
OM[5]	85.0	83.4	88.5	88.6	87.4
CP[5]	21.2	18.7	25.8	27.5	25.4
NDF[5]	52.0	61.5	46.5	43.2	53.3
IVOMD[6]	63.1	66.8	68.9	70.1	68.9

[1] CaO treated corn residue (53%), dried distillers grains (32%), solubles (14%), and urea (1%).
[2] CaO treated corn residue (54%), dried distillers grains (32%), and solubles (14%).
[3] CaO treated corn residue (44.5%), soy product (40%), and solubles (15.5%).
[4] SBM= soybean meal, PT = heat processed soybean meal, and SP = Soypass (LignoTech USA, Rothschild, WI) as soy product component in the pellet.
[5] % of DM.
[6] In vitro organic matter digestibility.

Table 3. Nutrient composition of basal forage diet in Exp. 1, 2, and 3

	Exp. 1[1]		Exp. 2[2]			Exp. 3[3]		
Nutrient	LQ	HQ	11-20-14	12-12-14	1-15-15	11-19-15	12-15-15	1-28-16
OM, % DM	92.3	91.9	89.5	85.9	75.8	90.9	81.0	83.9
OM Std. Dev.[4]	0.01	0.02	0.99	1.61	1.19	1.99	2.97	2.06
CP, % DM	7.1	15.1	7.1	9.1	7.30	7.0	8.5	11.3
CP Std. Dev.[4]	0.72	1.18	1.32	1.18	0.80	2.34	1.81	1.91
NDF, % DM	71.2	62.7	85.0	82.3	78.7	89.8	78.3	80.5
NDF Std. Dev.[4]	1.97	3.80	2.82	2.84	1.76	4.20	4.04	4.26
IVOMD, % DM[5]	49.3	60.9	67.4	54.2	54.7	56.5	53.6	44.6
IVOMD Std. Dev.[4]	2.62	2.33	3.36	1.32	1.39	5.30	2.42	4.46

[1] LQ = bromegrass hay; HQ = bromegrass silage (50%), alfalfa (37.5%), and sorghum silage (12.5%).
[2] Dryland corn residue sampled on Nov. 20, 2014, Dec. 12, 2014, and Jan. 15, 2015.
[3] Irrigated corn residue sampled on Nov. 19, 2015, Dec. 15, 2015, and Jan. 28, 2016.
[4] Standard deviation of the samples.
[5] In vitro organic matter digestibility.

Table 4. Effects of supplementing growing heifers with 0, 0.5, or 1.0% (of BW) with a corn byproduct pellet with either low or high quality forage in Exp. 1

	Low					High						*P*-Value		
Supplement, % BW	0	0.5	1.0	Lin[1]	Quad[2]	0	0.5	1.0	Lin[3]	Quad[4]	SEM	Int.[5]	Forage	Supp.
Initial BW, kg	279^{ab}	278^{b}	280^{a}	0.54	0.02	279^{ab}	280^{a}	278^{ab}	0.54	0.15	0.53	0.02	0.78	0.78
Ending BW, kg	304^{a}	327^{b}	340^{c}	<0.01	0.03	338^{c}	350^{d}	361^{e}	<0.01	1.00	1.68	<0.01	<0.01	<0.01
ADG, kg	0.30^{a}	0.59^{b}	0.72^{c}	<0.01	<0.01	0.70^{c}	0.84^{d}	0.99^{e}	<0.01	0.59	0.02	<0.01	<0.01	<0.01
Forage DMI, kg/d	7.4^{x}	6.6^{y}	5.6^{z}	<0.01	0.57	7.6^{x}	6.6^{y}	5.9^{z}	<0.01	0.17	0.16	0.38	0.35	<0.01
Total DMI, kg/d	7.4^{x}	8.1^{y}	8.7^{z}	<0.01	0.72	7.6^{x}	8.0^{y}	9.0^{z}	<0.01	0.13	0.16	0.40	0.31	<0.01
G:F	0.041^{a}	0.072^{b}	0.083^{c}	<0.01	<0.01	0.093^{d}	0.105^{e}	0.110^{e}	<0.01	0.23	0.003	<0.01	<0.01	<0.01
RDP balance, g/d	-26	71	175	-	-	420	435	485	-	-	-	-	-	-
MP balance, g/d	-87	-22	60	-	-	-62	7	112	-	-	-	-	-	-

[abcde] Means within a row differ when the interaction of forage nutritive value and supplement amount was significant ($P < 0.05$).
[xyz] Means within a row differ for supplement amount when main effect for supplement was significant ($P < 0.05$).
[1]Linear contrasts for supplement level with low quality forage.
[2]Quadratic contrasts for supplement level with low quality forage.
[3] Linear contrasts for supplement level with high quality forage.
[4] Quadratic contrasts for supplement level with high quality forage.
[5] Forage quality by supplement level interaction.

Table 5. Main effect of Gainpro on performance of growing steers grazing dryland corn residue in Exp. 2

	Gainpro[1]	No Gainpro	SEM	*P*-Value
Initial BW, kg	254	254	5.1	0.93
Ending BW, kg	278	278	5.3	0.91
ADG, kg	0.28	0.28	0.024	0.93
Forage DMI, kg/d[2]	5.17	5.11	0.144	0.78
Total DMI, kg/d	7.11	7.04	0.145	0.75
G:F	0.039	0.040	0.003	0.97
RDP balance, g/d	60	60	-	-
MP balance, g/d	131	129	-	-

[1] Provided bambermycins at 10 mg/steer daily.

[2] Estimated using 10 g of titanium dioxide, dosed daily, as a marker.

Table 6. Main effect of supplementation rate on performance of growing cattle grazing dryland corn residue in Exp. 2

					P-Value	
Supplement[1], % BW	0.3	0.7	1.1	SEM	Lin[2]	Quad[3]
Initial BW, kg	253	257	254	6.4	0.95	0.71
Ending BW, kg	252[a]	280[b]	301[c]	6.4	< 0.01	0.68
ADG, kg	-0.01[a]	0.28[b]	0.56[c]	0.03	< 0.01	0.89
Forage DMI, kg/d[2]	5.71[a]	5.07[b]	4.63[b]	0.18	< 0.01	< 0.01
Total DMI, kg/d	6.49[a]	7.00[b]	7.74[c]	0.18	< 0.01	< 0.01
G:F	-0.001[a]	0.040[b]	0.072[c]	0.004	< 0.01	0.24
RDP balance, g/d	11	58	105	-	-	-
MP balance, g/d	144	134	137	-	-	-

[abc] Means within a row with differing superscripts are different ($P < 0.05$).
[1] CaO treated corn residue (54%), dried distillers grains (32%), and solubles (14%).
[2] Linear contrasts for supplement level.
[3] Quadratic contrasts for supplement level.

Table 7. Main effect of Gainpro on performance of growing steers grazing irrigated corn stalks and supplemented with 2.3 kg DM of pellet in Exp. 3

	Gainpro[1]	No Gainpro	SEM	*P*-Value
Initial BW, kg	222	222	2.70	0.93
Ending BW, kg	251	251	2.70	0.96
ADG, kg	0.35	0.35	0.01	0.79

[1] Provided bambermycins at 20 mg/steer daily.

Table 8. Main effect of supplement protein source on performance of growing steers grazing corn stalks and supplemented with 2.3 kg DM of pellet in Exp. 3

Supplement[1]	SBM[2]	PT[2]	SP[2]	SEM	P-Value
Initial BW, kg	222	222	222	3.30	0.99
Ending BW, kg	252	251	249	3.31	0.92
ADG, kg	0.35	0.35	0.33	0.02	0.57
RDP balance,g/d	159	32	16	-	-
MP balance,g/d	124	251	238	-	-

[1] CaO treated corn residue (44.5%), soy product (40%), and solubles (15.5%).
[2] SBM= soybean meal, PT = heat processed soybean meal, and SP = Soypass (LignoTech USA, Rothschild, WI) as soy product component in the pellet.
[3] Forage intake used to calculate RDP and MP balances based off slope of intake as supplement rate increased from 0.7 to 1.1% of BW in Exp. 2.

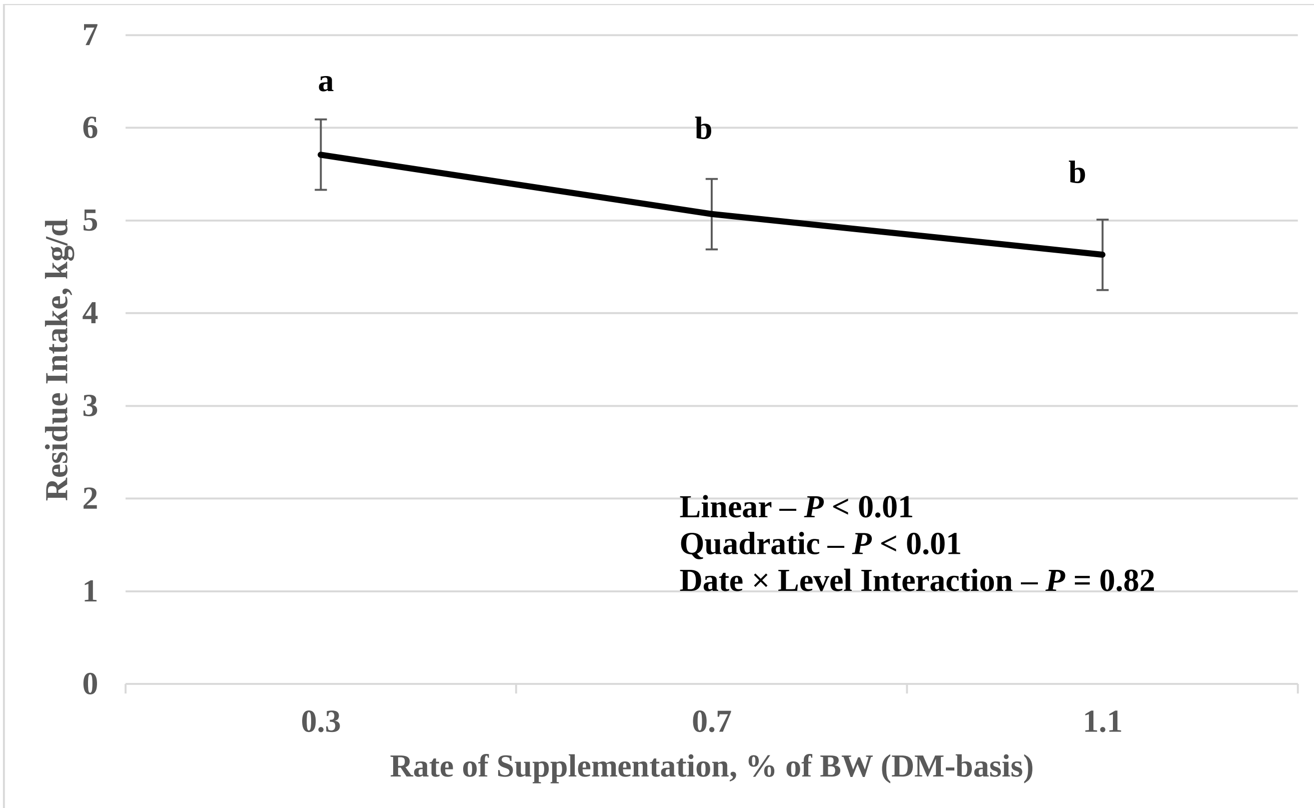

Figure 1. Effect of supplementation rate of pellet on residue intake of steers grazing corn residue in Exp. 2.

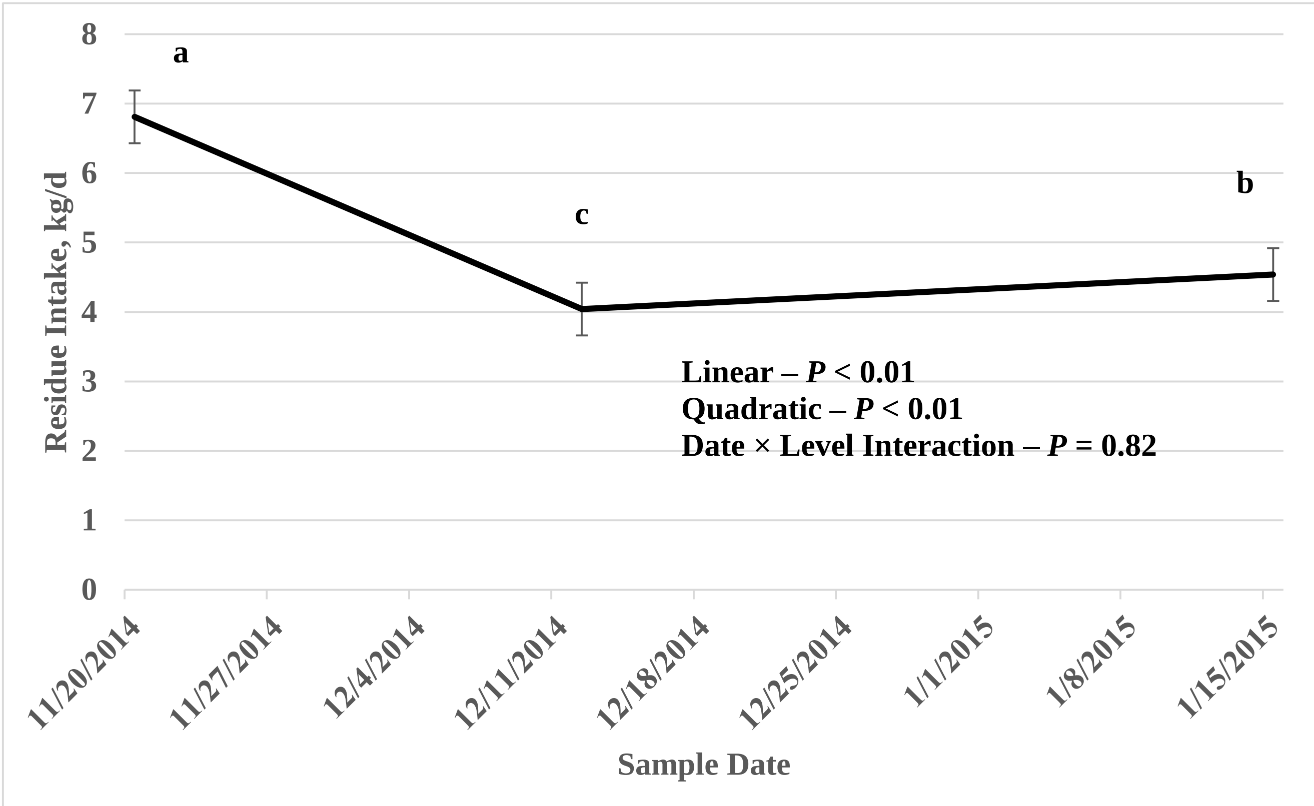

Figure 2. Effect of sampling date on residue intake of steers grazing corn residue in Exp. 2.