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Receiving and Backgrounding Phase Management: The Effects of Receiving Diet Roughage Source and Backgrounding Phase Rate of Gain on Performance of Feedlot Cattle

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RECEIVING AND BACKGROUNDING PHASE MANAGEMENT: THE EFFECTS OF RECEIVING DIET ROUGHAGE SOURCE AND BACKGROUNDING PHASE RATE OF GAIN ON PERFORMANCE OF FEEDLOT CATTLE

BY

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This dissertation is approved as a creditable and independent investigation by a candidate for the Doctor of Philosophy in Animal Science degree and is acceptable for meeting the dissertation requirements for this degree. Acceptance of this does not imply that the conclusions reached by the candidate are necessarily the conclusions of the major department.

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ABBREVIATIONS

ADF	Acid detergent fiber
ADG	Average daily gain
AFBW	Adjusted final body weight
BF	Batch fraction
BGR	Backgrounding phase growth rate
BW	Body weight
C	Celsius
cm	Centimeter
CP	Crude protein
d	Day
DDGS	Dried distillers grains
dL	Deciliter
DM	Dry matter
DMI	Dry matter intake
DP	Dressing percentage
EBF	Empty body fat
Exp.	Experiment
g	Gram
g	Gravity
G:F	Gain:feed
h	Hour
HCW	Hot carcass weight

in	Inch
kg	Kilogram
km	Kilometer
KPH	Kidney, pelvic, and heart fat
LM	Longissimus muscle
Mcal	Megacalorie
ME	Metabolizable energy
mg	Milligram
min	Minute
mL	Milliliter
mm	Millimeter
mmol	Millimolar
n	Number
NDF	Neutral detergent fiber
NEFA	Non-esterified fatty acid
NEg	Net energy for gain
r^2	Coefficient of determination
RDP	Rumen-degradable protein
RF	12^{th}-rib fat
RNC	Ruminant Nutrition Center
RUP	Rumen-undegradable protein
SBH	Soybean hull
SBM	Soybean meal

SDSU	South Dakota State University
sec	Second
SEM	Standard error of the mean
VFA	Volatile fatty acid
wk	Week
YG	Yield grade
yr	Year

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ABSTRACT

RECEIVING AND BACKGROUNDING PHASE MANAGEMENT: THE EFFECTS OF RECEIVING DIET ROUGHAGE SOURCE AND BACKGROUNDING PHASE RATE OF GAIN ON PERFORMANCE OF FEEDLOT CATTLE

ETHAN J. BLOM

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Management of cattle during the receiving and backgrounding phases can influence the performance of feedlot cattle. The receiving phase is a stressful time for cattle entering the feedlot and quickly adapting cattle to milled feed can impact their productivity. Silages are often viewed as less desirable feedstuffs in receiving diets for newly-weaned calves. The objective of this 2-yr study was to evaluate effects of roughage source in receiving diets on cattle performance, diet mixing, and diet integrity. Steer calves (yr 1, n = 180; yr 2, n = 210) were weaned and immediately transported 580 km. Calves were allotted to 1 of 3 receiving diets differing only in oat forage as the roughage source: oat hay (**HAY**), oat hay with added water (**HAYW**), or oat silage (**SIL**). Diets were fed for 42 d. Bunk samples were collected at feed delivery and post-meal and subjected to particle separation using a 12.7 mm screen. An initial overestimate of SIL dry matter (**DM**) in yr 1 caused steers on the SIL diet to be offered less ($P < 0.01$) DM than HAY or HAYW steers from d 1 to 16. Regardless, average daily gain (**ADG**) was not different ($P \geq 0.16$) during this time. Cumulatively, no differences in ADG ($P = 0.24$) or gain:feed (**G:F**; $P = 0.47$) were observed, but HAY steers consumed less ($P = 0.02$) DM than HAYW or SIL steers. In yr 2, SIL steers had greater ($P = 0.01$) ADG during the initial 14 d compared to HAY or HAYW steers with no difference in dry

matter intake (**DMI**; *P* = 0.18); thus SIL steers had greater G:F (*P* = 0.01). Cumulatively, no differences in ADG were observed in yr 2 (*P* = 0.21); however, SIL steers consumed less (*P* < 0.01) DM than HAY or HAYW steers which resulted in greater G:F (*P* = 0.01). Circulating lipid concentrations tended to be greater for HAY cattle compared to HAYW or SIL cattle (*P* = 0.09). The magnitude of change in the proportion of larger particles in the bunk from delivery to post-meal (i.e. the effect or sorting) was nearly 4-fold greater for HAY than SIL in yr 1 (*P* = 0.04) and 3.5-fold greater in yr 2 (*P* = 0.05). As batch fraction (**BF**) increased, when batch was offloaded from the mixer, the proportion of larger particles delivered also increased (*P* < 0.01). Conversely, cumulative ADG decreased (*P* < 0.01) as BF increased. In conclusion, SIL had no adverse effects on the growth performance of newly-weaned calves. Diet mixing and integrity can be improved by adding SIL in receiving diets, as indicated by more uniformity of particle size throughout the batch and less change in particle size uniformity from delivery to post-meal. Effects of varying backgrounding phase growth rate (**BGR**) on subsequent finishing phase performance and carcass characteristics were evaluated in 2 experiments. In Exp. 1, 240 steers were randomly assigned to 1 of 3 BGR treatments from study initiation to 397 kg: 0.91 kg/d (**LOW**), 1.13 kg/d (**MID**), or 1.36 kg/d (**HIGH**). Net energy equations were used to prescribe sufficient DM to achieve each the BGR for each group. When each treatment reached the target body weight (**BW**) of the backgrounding phase, it was transitioned to a finishing diet. From this point on, treatments were managed similarly. The cattle within each treatment were harvested independently at a common 12^{th}-rib fat endpoint. By design, backgrounding phase ADG linearly increased (*P* < 0.01). The backgrounding phase lasted 92, 78, and 62 d for LOW, MID, and HIGH,

respectively. Finishing phase ADG and DMI were linearly decreased with greater BGR ($P < 0.01$), but no difference in G:F was observed ($P \geq 0.35$). Cumulatively, ADG linearly increased with greater BGR ($P < 0.01$), but G:F was not different ($P \geq 0.17$). Hot carcass weight (**HCW**) decreased linearly with greater BGR ($P < 0.01$). Marbling score responded quadratically as it increased from LOW to MID, then decreased with HIGH BGR ($P = 0.02$). In Exp. 2, 144 steers were randomly assigned to the same 3 treatments used in Exp. 1. Backgrounding phase endpoint BW was 408 kg in Exp. 2. As expected, backgrounding phase ADG linearly increased ($P < 0.01$). The backgrounding phase lasted 76, 61, and 54 d for LOW, MID, and HIGH, respectively. Finishing phase ADG and DMI linearly decreased ($P \leq 0.02$) as BGR increased, with no difference in G:F ($P \geq 0.16$). Cumulative ADG linearly increased with greater BGR ($P = 0.02$) while G:F also tended to increase ($P = 0.07$). Restricting BGR linearly increased HCW ($P = 0.04$). Similar to Exp. 1, marbling score tended to respond quadratically to increasing BGR as it increased from LOW to MID, then decreased between MID and HIGH ($P = 0.06$). When regressing marbling scores from Exp. 1 and 2 on BGR, we found that marbling responded quadratically ($P = 0.03$) and BGR accounted for approximately 8% of the variation in marbling score. Restricting BGR can result in improved finishing phase performance and greater final BW; however, a greater number of days on feed is required. Increases in HCW can also be achieved with lesser BGR, although optimum carcass quality may be realized with only modest restriction in BGR.

CHAPTER ONE:

INTRODUCTION AND LITERATURE REVIEW

INTRODUCTION

Management strategies during the receiving and backgrounding phases are impactful on the ultimate performance of cattle in the feedlot. The receiving phase is a period of stress management for newly-received calves. Stresses associated with weaning, marketing, and transportation are common for received calves. To complicate matters, this is also a time of depressed appetite leading to decreased voluntary nutrient intake. This makes nutritional management decisions extremely important in reducing stress as much as possible while promoting greater nutrient intake to support growth.

Backgrounding phase management similarly plays a role in ultimate cattle performance in the feedlot. Backgrounding is often characterized by a period of sub-maximal average daily gain (**ADG**). Reduced ADG during the backgrounding phase typically results in periods of compensatory gain once cattle are allowed to consume greater amounts of dietary energy. Backgrounding can delay lipid deposition and allow lean tissue maturation, ultimately resulting in greater body weight (**BW**) at a given fat endpoint. Manipulation of these receiving and backgrounding strategies can be a useful method of altering cattle productivity in the feedlot.

LITERATURE REVIEW

Receiving cattle

The period in which new cattle are received into the feedlot is critical and extensive research has been performed to glean a better understanding of how successful navigation through the receiving phase can impact growth performance. The greatest challenge during the receiving phase is overcoming numerous stresses that cattle may experience. These include stresses associated with weaning, transportation, commingling, castration, dehorning, deprivation of feed and water, vaccination, adaptation to new social hierarchy, and transition to novel feed ingredients, among others (Loerch and Fluharty, 1999). Indeed, Preston indicated that "The basic problem is that cattle do not eat and become sick when they first arrive at the feedlot" (2007). Hutcheson (1987) found that dry matter intake (**DMI**) of healthy calves during the first week post-arrival is only 1.6% of BW while morbid calves eat less than 1% of BW. Energy required to respond to an immune challenge is likely appreciable. Few data are available quantifying the energetic cost of an activated immune system. Dairy cattle under a lipopolysaccharide-induced immune challenge require between 265 and 516 g of glucose per 12-h period to maintain blood glucose levels similar to control cattle (Kvidera et al., 2016; Kvidera et al., 2017). Newly-received cattle consuming small amounts of feed may have a reduced ability to mount an immune response. This emphasizes the importance of getting newly-received cattle to eat as soon as possible upon entry into the feedlot. While all stressors cannot be mitigated by nutrition, adequate nutrition can enable the animal to prepare for stress, reduce the effects of stress, and recover from stress (Cole, 1982). Many nutritional aspects have been studied in attempt to elicit improvements in receiving phase growth performance: dietary energy or crude protein (**CP**) concentrations, dietary mineral levels, preconditioning, feeding and watering behavior, and ensiled vs. dry feeds, among others. Improvements in performance during the receiving phase can often be maintained throughout subsequent feeding periods (Lofgreen et al., 1975; Lofgreen, 1987; Galyean et al., 1993).

Protein in receiving diets

Protein levels in receiving diets have been an often-studied topic. Since DMI of newly-received calves is often low, it seems logical that protein concentration in the diet may need to be increased. Eck et al. (1988) reported newly-received heifers consuming a 12.5% CP diet consumed more and grew at a 30% faster rate than heifers consuming a 10.5% CP diet. Cole and Hutcheson (1990) reported that while the daily required grams of CP did not differ between stressed and non-stressed calves, increasing dietary CP from 12 to 16% for stressed calves improved ADG 50% in one study but was not different in a subsequent study. This increase in dietary CP concentration was likely necessary to meet requirements when DMI was low in stressed calves. Galyean et al. (1993) used soybean meal (**SBM**) to increase the CP concentration of receiving diets from 12 to either 14 or 16% and observed increased DMI, ADG, and gain:feed (**G:F**) as dietary CP concentration increased during the 42-d receiving phase. Fluharty and Loerch (1995) explored the effects of a wider range (12 to 18%) of dietary CP values for newly-received calves and found a linear increase in ADG and G:F as CP concentration increased during the first week after arrival. However, these improvements in ADG and G:F during the first week were negated over the entire 6 wk receiving phase, and no difference was observed in DMI when evaluated over the entire receiving phase. These authors also measured effects of an even wider range of receiving diet CP concentrations, from 11 to 26% of diet. Increasing dietary CP resulted in a linear increase in ADG during the first week post-receiving (Fluharty and Loerch, 1995).

In addition to concentration of dietary CP, CP source has also been researched extensively in the diets of receiving cattle. A primary concern regarding dietary CP in receiving diets is site of protein degradation. The proportion of rumen-degradable protein (**RDP**) and rumen undegradable protein (**RUP**) may be as important, if not more important than level of CP in the diet (Preston and Smith, 1974; Eck et al., 1988). While it is necessary to provide ample RDP to support ruminal fermentation of carbohydrates, strategies have been employed to shift protein digestion to the small intestine. Preston and Smith (1974) treated SBM with formaldehyde to allow a greater proportion of the protein to escape ruminal degradation. These authors found that supplementing new feeder calves with 0.23 kg of protected SBM increased ADG to the same extent as 0.45 kg untreated SBM. Furthermore, in 2 studies Eck et al. (1988) reported that a combination of slowly degraded blood meal and corn gluten meal promoted greater ADG and G:F in receiving cattle compared to more rapidly ruminally degraded protein sources such as cottonseed meal or urea. Furthermore, Fluharty and Loerch (1995) also measured the effects of different protein sources on growth performance of receiving cattle. These authors reported that spray-dried blood meal provided an 11% improvement in G:F over SBM, despite only numerical differences in DMI and ADG during the 6-wk receiving study.

It appears that both amount and source of CP can play an important role in growth performance of newly-received feedlot cattle. Cattle typically respond to increased dietary CP, especially during the early weeks of receiving; however, this response is often dependent on a variety of factors, including BW and DMI. Increasing dietary RUP can also improve growth performance in newly received feedlot calves. Indeed, Preston (2007) recommends that 60% of dietary CP be in the form of RUP.

Energy density of receiving diets

In addition to the necessity of adequate dietary CP in receiving diets, energy density is another important consideration. Feedstuffs familiar to newly-weaned calves coming from forages such as dry hays, have relatively low energy densities. Conversely, feedstuffs with greater energy densities may better meet the nutritional requirements of newly-received calves but are unfamiliar to these animals. Lofgreen et al. (1975) fed newly-received, highly-stressed calves diets with net energy for gain (**NEg**) concentrations of either 0.84, 1.01, or 1.10 Mcal/kg. Cattle consuming the 1.10 Mcal/kg NEg diet returned to their purchase weight 2 and 5 d sooner than cattle consuming the 1.01 and 0.84 Mcal/kg NEg diets, respectively. Cattle consuming the most energy dense diet also had greater ADG during the first few weeks and cumulatively throughout the entire 63 d study compared to cattle consuming less energy dense diets. The same authors also compared diets with NEg concentrations of 1.01, 1.10, and 1.19 Mcal/kg. In this case, the 2 most energy dense diets provided the same advantage in ADG during the first 28 d over the least energy dense diet, despite calves fed the 1.19 Mcal/kg diet exhibiting the lowest ADG during the first week. These calves were managed similarly after the 28-

d receiving phase and the weight advantage gained with the 2 most energy dense diets was maintained throughout the 253-d feeding period (Lofgreen et al., 1975).

In a similar study, Lofgreen et al. (1980) fed high-stress, newly-weaned calves diets with either 0.57, 0.75, and 0.90 Mcal/kg NEg. These authors reported similar improvements in ADG for cattle fed 0.75 and 0.90 Mcal/kg NEg diets over compared to cattle fed the 0.57 Mcal/kg NEg diet for the first 28 d of the study; however, after the next 28 d in which all treatments were fed the same diet, the 0.75 Mcal/kg NEg group had a cumulative ADG advantage over either of the other 2 groups. Furthermore, Lofgreen (1987) reported that a 75% concentrate diet allowed incoming cattle to exhibit greater ADG than cattle fed native grass hay with supplemental protein. Others (Fluharty and Loerch, 1996) have noted a linear increase in DMI as dietary concentrate was increased from 70 to 85% in newly-received calves, although no difference was observed for ADG or G:F during the 28 d study. In calves fed either a high- (1.17 Mcal/kg NEg) or low-energy (1.01 Mcal/kg NEg) diet, DMI was 16% greater in calves fed the high-energy diet; however, ADG was not different (Pritchard and Mendez, 1990). Thus, G:F was poorer for calves fed the high-energy diet compared to those fed the low-energy diet during the 28-d receiving phase. In a similar study using high- and low-energy receiving diets, Pritchard (1987) reported a 7% improvement in ADG with no difference in DMI for calves consuming the high-energy receiving diet, thus similarly improving G:F. It seems that high-concentrate diets typically provide an opportunity for increased ADG during the receiving phase compared to lower-energy diets. However, caution should be exercised when interpreting these data as gut fill differences can account for a portion of the differences in weight gain between high-forage and high-concentrate diets (Lofgreen et al., 1981).

Roughage sources in receiving diets

The source of dietary roughage for receiving calves can be important for facilitating cattle to adapt to a new diet. Feedstuffs such as dry hays are most familiar to cattle coming off pasture; however, many feedlots may want to utilize ensiled forages typically fed throughout the feeding period in the receiving phase. The issue with ensiled feeds is that cattle are not familiar with silage and thus do not recognize it as feed, regardless of when they first experience it (Preston, 2007).

Preston and Kunkle (1974) received yearling steers on either chopped hay, corn silage, chopped hay initially then gradually transitioned to corn silage after 12 d. During the initial 12 d, cattle consuming chopped hay gained 38% faster than those cattle consuming corn silage (2.33 vs 1.68 kg/d). From 12 to 19 d the group of cattle being transitioned from hay to silage lost weight while the cattle consuming either hay or silage continued to gain weight. From 19 to 26 d, the silage-fed steers compensated and grew 45% faster than either of the other two groups. Cumulatively, cattle fed either chopped hay or corn silage had a similar advantage in ADG compared to the cattle started on hay and transitioned to silage. Additionally, silage-fed cattle had improved G:F, which would be expected as that diet also had the greatest energy content (Preston and Kunkle, 1974). In a similar study using calves, those fed corn silage had poorer gains than calves eating hay initially, but when those eating hay were transitioned to silage, the reverse was true

(Preston and Smith, 1973). These periodic differences negated each other cumulatively, resulting in no differences in overall ADG or gain efficiency during the 54-d trial.

Bartle et al. (1987) fed receiving yearlings either chopped alfalfa hay or corn silage/milo-based diet. Interestingly, cattle consumed a greater amount of the milled feed on d 1 compared to those offered alfalfa hay. The same was observed over the first week in the feedlot; however, the authors note that the animals used in this study appeared to be primarily long yearlings and there was a chance that those cattle had previously been familiarized with mixed rations (Bartle et al., 1987).

Cattle fed alfalfa hay upon receiving exhibited greater DMI and ADG than cattle fed millet hay (Lofgreen et al., 1981). To compare receiving diets with different roughage sources, Koers et al. (1975) fed cattle diets containing 40% of either cottonseed hulls, corn silage, or corn bran. Cattle fed cottonseed hulls had greater DMI and improved ADG compared to those consuming corn silage or corn bran.

It seems that silages can be an effective roughage source in the diets of receiving cattle. While cattle often consume a slightly lesser quantity of silage initially, silage-fed calves typically have improved performance over the duration of the receiving phase compared to those cattle received on dry hay-based diets.

Backgrounding cattle

The backgrounding phase of cattle feeding is the production phase following weaning, but prior to the finishing period in the feedlot (Thomson and White, 2006). The feeding programs implemented during backgrounding are often the least understood of all the production phases (Peel, 2003). These backgrounding programs can vary widely in their length, approach, and ultimately, in the production goals of commercial producers. Terminology used to describe these programs can also vary, as similar practices can be referred to as “backgrounding” which is often more common in northern regions, or “stocker”, which is more common in southern regions (Peel, 2003). Despite all this variability, a common quality of a backgrounding program is feeding to maintain a less than maximal growth rate in order to curb lipid deposition and encourage maturation of lean tissue and bone (Block et al., 2001). This is in contrast to “calf-fed” production systems where weaned calves are placed in the feedlot and fed to achieve maximal growth rates. Results of this altered proportion of tissue deposition by backgrounding include, but are not limited to, allowing smaller-framed cattle to reach a greater (more desirable) weight at a similar market-ready fat endpoint (Byers, 1982), increase mature size (Owens et al., 1993), provide a desired ADG, offer a market outlet for roughages (Sip and Pritchard, 1991), and shift the timing and quantity of cattle entering the feedlot (Peel, 2003).

Forage- vs concentrate-based backgrounding diets

Many different nutritional strategies have been employed during the backgrounding phase to accomplish the goals described above. Grazed forages can be used to achieve the less than maximal growth rate required of a backgrounding period. Regionally, this depends on the type of available forage and the variability in forage growth within season. Alternatively, many cattle are backgrounded in confinement. High-forage diets based on dry hay or ensiled forages are often utilized in confinement, and fed to the point where economical conversion of forage to live weight gain is no longer achievable (Marlowe, 1983). Another calf backgrounding approach involves restricting intake of a high-concentrate diet. Concentrates are generally more economical per unit of energy and can be much easier to store and handle compared to bulky forages like hay (Sip and Pritchard, 1991). However, limiting DMI of these high-concentrate diets could lead to increased consumption rate of rapidly-fermentable carbohydrate and ultimately an increased risk of digestive disorders (Sip and Pritchard, 1991). Digestive disorders such as ruminal acidosis can cause long-term impacts on ruminal volatile fatty acid (**VFA**) absorption, and ultimately, efficiency of feed use (Krehbiel et al., 1995). Using either forage- or concentrate-based backgrounding programs can potentially impact subsequent performance in the feedlot.

Ridenour et al. (1982) backgrounded cattle to 2 different BW on either a high-concentrate diet, a 50% concentrate diet, or on wheat pasture. Following backgrounding, cattle were finished on the high-concentrate diet until slaughter. High-concentrate fed cattle had greater ADG than cattle backgrounded on 50% concentrate diets or wheat pasture. During the finishing phase, cattle backgrounded to a lighter BW on the 50% concentrate diet or wheat pasture had increased ADG compared to those grown to a heavier weight or the cattle on a high-concentrate diet. Cumulatively, cattle backgrounded to a lighter BW on a high-concentrate diet or 50% concentrate diet exhibited improvements in ADG over all other treatments.

Loerch (1990) backgrounded cattle on ad libitum intake of a corn silage-based diet or restricted intake 20 or 30% of a high-concentrate diet. The nutrient composition of the high-concentrate diets was such that when DMI was restricted either 20 or 30%, dietary energy was sufficient to match the backgrounding rate of gain of the cattle when consuming the corn silage diet at ad libitum. By design, ADG during the 85-d backgrounding phase was not different among treatments and DMI decreased with increasing diet energy content, thus the G:F for the 20 and 30% restricted cattle was improved 31 and 44%, respectively. Performance during the subsequent 118 d finishing phase was similar for all three groups of cattle, indicating that backgrounding diet substrate had little effect on finishing performance given similar backgrounding ADG were achieved. Similarly, Sip and Pritchard (1991) backgrounded steer calves that had ad libitum access to corn silage-based diets and limit fed high-moisture corn-based diets to achieve a similar ADG for 85 d. Backgrounding phase ADG was similar for cattle on both diets and no subsequent effect on performance was detected throughout the 94 d finishing period.

Backgrounding phase rate of gain

Rate of gain achieved during the backgrounding phase plays an important role in subsequent performance of cattle during the finishing phase. Periods of sub-maximal rates of gain can result in subsequent periods of compensatory growth (Osborne and Mendel, 1915; Winchester and Howe, 1955), although Hogg (1991) cautions against confusing *true* compensatory growth with a recovery of weight-for-age (i.e. a weight at a given day of age) which is actually the case in many research trials. While this recovery of weight-for-age is typically characterized by an extended period of *normal* growth, *true* compensatory growth is illustrated by period of accelerated growth rate compared to animals of similar genetics and environment. Nonetheless, this period of more rapid BW gain is typically characterized by increased DMI and G:F compared to animals of a similar BW (Pritchard, 1996). This improvement in G:F has been attributed to increased DMI (Tayler, 1959), greater proportion of gain as protein (Fox et al., 1972; Carstens et al., 1991), and improved efficiency of metabolizable energy (**ME**) use (Meyer et al., 1965; Fox et al., 1972). Tayler (1959) wintered cattle on low or high plane of nutrition before spring realimentation and concluded that increased DMI upon refeeding was responsible for increased ADG of compensating steers. Carstens et al. (1991) restricted cattle to gain 25% the rate of their full-fed contemporaries from 245 to 325 kg, after which they were realimented to *ad libitum* intake. Steers experiencing compensatory growth had a 39% greater protein accretion rate than steers under continuous growth. In steers fed either near maintenance for approximately 6 months before refeeding, or fed ad libitum throughout, Fox et al. (1972) found that compensating steers had a 26% increase in the percent of gain as protein compared to their full-fed contemporaries. However, compensating steers deposited proportionally more protein than fat than the ad libitum-fed cattle early in the refeeding period, but proportionally more fat than the ad libitum-fed cattle late in the refeeding period. In addition to increased proportion of gain as protein, these authors also indicated that a more efficient use of ME and protein could be partially responsible for compensatory growth (Fox et al., 1972). These data confirmed earlier work by Meyer et al. (1965) which reported an increase in the partial efficiency of feed utilization for compensating steers compared to full-fed steers. Improvements in the efficiency of energy capture for compensating animals is a result of altered energy demands by digestive organs. Birkelo et al. (1991) reported a 7% decrease in fasting heat production for cattle on a low plane of nutrition compared to cattle on a high plane of nutrition. Decreases in fasting heat with a lowered plane of nutrition have been largely attributed to decreased organ weights. Weights of liver or gastrointestinal tract have been shown to proportionally decrease with decreased ME intake in cattle (Johnson et al., 1990; Carstens et al., 1991).

Severity of reduction in plane of nutrition, and thus ADG, during the backgrounding phase can have a large impact on the level of compensatory gain achieved in the following feeding periods. Choat et al. (2003) grazed cattle on either winter wheat or native rangeland during backgrounding and reported greater ADG for cattle backgrounded at a slower rate on native rangeland. When cattle were fed to gain 0.9 or 1.4 kg/d during a 98-d growing phase, Felix et al. (2011) found that cattle backgrounded at a slower rate grew 14% faster during the finishing phase. However, Loerch and Fluharty (1998) backgrounded steers at 1.03, 1.22, or 1.40 kg/d but were unable to detect any differences in finishing phase ADG, although an 8% numerical increase in ADG was reported for steers backgrounded at 1.03 kg/d vs 1.40 kg/d. Lancaster et al. (2014) reviewed the available data and found that finishing ADG was negatively correlated with backgrounding ADG. This indicates that more severe nutrient restriction in the backgrounding phase allowed cattle to exhibit greater compensatory growth during subsequent periods of unrestricted growth. In addition to greater finishing phase ADG, cattle backgrounded at a lesser ADG may exhibit greater final weights, especially when cattle are harvested at similar fat endpoint (Sainz et al., 1995). Indeed, mature size of cattle can be increased by backgrounding cattle slowly on plant residues or pasture compared to placing cattle directly into the feedlot (Owens et al., 1993). In addition to mature size, carcass characteristics can also be altered with differing backgrounding phase ADG.

The effects of backgrounding phase ADG on carcass characteristics are inconsistent, and often depend on slaughter endpoint determination. In a 2-year study comparing backgrounding diets based on either corn silage or hay, hot carcass weight (**HCW**) was increased with the hay diet the first year, but unchanged in year 2 (Nelson et al., 1980). Longissimus muscle area (**LMA**) was not different the first year but increased for corn silage-fed cattle in year 2. Ridenour et al. (1982) observed no differences in HCW for cattle backgrounded on a high-concentrate diet, 50% concentrate diet, or wheat pasture. However, these authors did observe increased LMA for those cattle backgrounded on a high-concentrate diet compared to other backgrounding strategies when cattle were harvested at a common fat endpoint (Ridenour et al., 1982). Conversely, when cattle were backgrounded for either 70 or 126 d, no difference in LMA was observed, but HCW was increased 4% when cattle were backgrounded longer (Block et al., 2001). When Loerch and Fluharty (1998) backgrounded steers at differing rates of gain, no differences in carcass characteristics were observed. Choat et al. (2003) reported compensating steers previously backgrounded on native range had decreased HCW, dressing percent, and LMA compared to cattle backgrounded on wheat pasture, with no difference in the ratio of LMA:HCW. Others have reported no difference in carcass characteristics when cattle were backgrounded at different rates of gain (Loken et al., 2009).

Marbling score is often unaffected by backgrounding phase plane of nutrition (Ridenour et al., 1982; Block et al., 2001; Loken et al., 2009). Conversely, Choat et al. (2003) reported a 9% decrease in marbling scores for cattle backgrounded at a low rate of gain on native range compared to cattle backgrounded on wheat pasture. Felix et al.

(2011) found that when cattle were backgrounded on dried distillers grain- (**DDGS**) based diets, an increased ADG resulted in increased marbling scores, while in dry-rolled corn-based diets, an increased ADG resulted in decreased marbling scores.

Periods of sub-maximal backgrounding ADG can result in greater ADG and G:F during subsequent feeding periods. This can be a result of increased DMI, a greater proportion of gain as protein, or an increase in the efficiency of ME use. Carcass characteristics can similarly be altered with different rates of backgrounding ADG, but the results can often be dependent on harvest endpoints.

Conclusion

In summary, receiving and backgrounding management strategies can play an important role in the subsequent feeding phase performance and ultimately on carcass traits. The receiving phase is a stressful period for calves often characterized by low DMI. Dietary protein level and source, energy density, and roughage sources are all important in ensuring cattle consume adequate quantities and proportions of nutrients upon arrival into the feedlot to support growth. Improved growth performance during this phase can have lasting effects until harvest. Backgrounding phase management strategies also play an important role in the finishing performance of cattle. These backgrounding strategies typically aim to maintain a sub-maximal ADG to slow lipid deposition and promote maturation of lean tissue. This can be done using *ad libitum* feeding of forage-based diets or programmed feeding of high-concentrate diets. Compensatory growth is often achieved following the backgrounding phase, with a concomitant increase in mature size. Rate of backgrounding weight gain can influence subsequent finishing phase performance, with a greater degree of nutrient limitation resulting in greater subsequent compensatory gain. Carcass characteristics can similarly be affected by backgrounding phase management but are somewhat variable. The primary objective of beef cattle production is to produce safe, healthful, profitable beef for human consumption. Manipulation of management strategies during the receiving and backgrounding phases can be a useful method to alter cattle productivity in the feedlot.

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CHAPTER TWO:

EVALUATION OF HAY AND SILAGE IN RECEIVING DIETS OF NEWLY-WEANED CALVES OVER 2 YEARS

ABSTRACT

The receiving phase is a stressful time for cattle entering the feedlot and quickly adapting cattle to milled feed can impact the productivity. Silages are often viewed as less desirable feedstuffs in receiving diets for newly-weaned calves. The objective of this 2-yr study was to evaluate effects of roughage source in receiving diets on cattle performance and diet mixing and integrity. Steer calves (yr 1, n = 180; yr 2, n = 210) were weaned and immediately transported 580 km. Calves were allotted to 1 of 3 receiving diets differing only in oat forage as the roughage source: oat hay (**HAY**), oat hay with added water (**HAYW**), or oat silage (**SIL**). Diets were fed for 42 d. Bunk samples were collected at feed delivery and post-meal and subjected to particle separation using a 12.7 mm screen. An initial overestimate of SIL dry matter (**DM**) in yr 1 caused steers on the SIL diet to be offered less ($P < 0.01$) DM than HAY or HAYW steers from d 1 to 16. Regardless, average daily gain (**ADG**) was not different ($P \geq 0.16$) during this time. Cumulatively, no differences in ADG ($P = 0.24$) or gain:feed (**G:F**; $P = 0.47$) were observed, but HAY steers consumed less ($P = 0.02$) DM than HAYW or SIL steers. In yr 2, SIL steers had greater ($P = 0.01$) ADG during the initial 14 d compared to HAY or HAYW steers with no difference in dry matter intake (**DMI**; $P = 0.18$); thus SIL steers had greater G:F ($P = 0.01$). Cumulatively, no differences in ADG were observed in yr 2 ($P = 0.21$); however, SIL steers consumed less ($P < 0.01$) DM than HAY or HAYW steers which resulted in greater G:F ($P = 0.01$). Circulating non-esterified fatty acid concentrations tended to be greater for HAY cattle compared to HAYW or SIL cattle ($P = 0.09$). The magnitude of change in the proportion of larger particles in the bunk from delivery to post-meal (i.e. the effect or sorting) was nearly 4-fold greater for HAY than

SIL in yr 1 ($P = 0.04$) and 3.5-fold greater in yr 2 ($P = 0.05$). As batch fraction (**BF**) increased, when batch was offloaded from the mixer, the proportion of larger particles delivered also increased ($P < 0.01$). Conversely, cumulative ADG decreased ($P < 0.01$) as BF increased. In conclusion, SIL had no adverse effects on the growth performance of newly-weaned calves. Diet mixing and integrity can be improved by adding SIL in receiving diets, as indicated by more uniformity of particle size throughout the batch and less change in particle size uniformity from delivery to post-meal.

Keywords: cattle, diet mixing, growth performance, receiving, roughage source, silage

INTRODUCTION

Calves that undergo weaning and shipping can experience considerable amounts of stress and depressed dry matter intake (**DMI**). Adapting newly-received calves in the feedlot to milled feed can be an important aspect to the productivity of these calves. The DMI of healthy receiving calves is only about 1.6% of body weight (**BW**), while morbid receiving calves consume less than 1% of BW (Hutcheson, 1987). It is important for calves to increase their DMI and minimize the time spent in a negative energy balance to be productive in the feedlot. Harvested hay is often used as a roughage source for newly-received calves as it is thought to be a familiar feed to calves that have previously consumed forage. Ensiled feeds are often thought to be less desirable in receiving diets because of their unfamiliar smell and taste. However, increased moisture content of ensiled feeds may improve diet mixing and integrity compared to dry hays. The objective of this experiment was to evaluate the effects of hay, silage, or hay with added water as the roughage source in receiving diets on calf performance and diet mixing and integrity.

MATERIALS AND METHODS

All experimental protocols were approved by the South Dakota State University (**SDSU**) Institutional Animal Care and Use Committee (approval # 17-076E). These experiments were repeated over 2 consecutive years at the SDSU Ruminant Nutrition Center (**RNC**).

A comparison of parameters in the 2-yr receiving study is presented in Table 2.1. Angus and Angus-based crossbred steer calves (yr 1, n = 180; yr 2, n = 210) were sourced from 2 ranches in western South Dakota. They were weaned and transported approximately 580 km to the RNC near Brookings, SD. Upon arrival at the feedlot, calves were placed into pens (10 steers/pen) and allowed access to water and long stem grass hay overnight. The next morning calves were processed, which included obtaining individual BW, administering individual eartags, vaccination for viral (Bovi-Shield Gold 5, Zoetis, Kalamazoo, MI) and clostridial diseases (Ultrabac 7, Zoetis) and treated for internal and external parasites (Cydectin, Bayer, Shawnee, KS). Cattle were stratified by ranch of origin and processing BW, then randomly assigned to dietary treatment and subsequently to pen replicate (yr 1 = 6 replicates per treatment; yr 2 = 7 replicates per treatment).

Treatments consisted of 3 diets which differed only in oat forage as the roughage source. Diets (Table 2.2) included either oat hay (**HAY**), hay with added water (**HAYW**), or oat silage (**SIL**). Hay and silage were harvested from the same oat crop from the same field. Oat silage was harvested with a forage harvester and chopped to a length of 1.9 cm (0.75 in). Oat hay was ground through an 8.9 cm (3.5 in) screen with a tub grinder (Haybuster Model 1130; DuraTech Industries International, Inc., Jamestown, ND). Previously, we had determined that the practical water holding capacity of the oat hay exceeded 4 parts hay:1 part water. By mixing water into the hay at 4:1, water was added at 10% of the HAYW diet DM. Diets also included soybean hulls (**SBH**) and a pelleted supplement that was the carrier for added monensin, vitamins, and minerals. All diets were formulated to exceed nutrient requirements of growing steers (NASEM, 2016). Cattle were allowed access to long-stem grass hay on the first day milled feed was offered (Table 2.1). Milled diets were top dressed on the long-stem hay to facilitate adaptation. Diets were mixed in a reel-type mixer (Roto-Mix 84-8; Roto-Mix, Dodge

City, KS). Oat forage was the first ingredient added to the mixer. If the diet included added water, it was sprinkled directly onto the oat hay. The hay and water were allowed to mix for 30 sec. Pelleted supplement was then added to the mixer followed by soybean hulls. Diets were allowed to mix for 4 min (20 full mixer revolutions). Three pens were fed out of each batch in yr 1, while either 3 or 4 pens were fed out of each batch in yr 2. Cattle were fed twice daily, and bunks were managed according to a clean bunk management system. Diets were formulated to provide 28 mg/kg monensin. In yr 1, diets were reformulated on d 23 to adjust for decreasing crude protein (**CP**) content of the oat silage. Feed records were compiled weekly and feed batching records and weekly ingredient assay values were used to calculate actual diet formulation and composition values. Feed samples were dried in a forced air oven at 60°C until a constant weight was maintained to determine dry matter (**DM**), then ground through a 1 mm screen (Thomas-Wiley Laboratory Mill Model 4, Thomas Scientific USA, Swedesboro, NJ). Ground samples were analyzed for DM (method no. 935.29; AOAC, 2012), CP (Kjeldahl procedure; Method No. 951.01; AOAC , 2012), neutral detergent fiber (**NDF**) and acid detergent fiber (**ADF**; Goering and Van Soest, 1970), and ash content (method no. 942.05; AOAC, 2012).

The initial BW was the BW obtained during processing. Cattle were subsequently weighed on d 16 and 42 in yr 1 and on d 14 and 42 in yr 2. All individual BW were recorded in the morning before cattle were fed.

Bunk samples were collected from each pen in both years. In yr 1, samples were collected on d 32 during the afternoon feed delivery. In yr 2, samples were collected during the morning feed delivery; pen replicates 1 through 3 of each treatment were sampled on d 22 and 30 and pen replicates 4 through 7 were sampled on d 24 and 29 (Table 2.1). At each bunk sampling event, samples were collected at the time of feed delivery and again after about 75% of feed was consumed. Bunk samples at the time of delivery were collected into a wooden sampling box placed in the middle of the bunk as feed was unloaded from the delivery wagon. Post-meal bunk samples were based upon a visual assessment of when approximately 75% of delivered feed was consumed, independent of feed delivery sequence. Post-meal bunk samples were obtained by compositing four, 15-cm (6-in) cross-sections of bunk contents at evenly spaced intervals along the length of the bunk. Immediately after post-meal sample collection, the weight of the remaining feed in the bunk was recorded to determine proportion of feed consumed. Upon collection, bunk samples were subjected to particle separation using a 12.7 mm (0.5 in) brass sieve (The W. S. Tyler Company, Mentor, OH). The weights of the material that passed through the sieve (smaller particles) and of the material that was retained (larger particles) were recorded. The DM content of the smaller and larger particle fractions was determined by drying in a forced air oven at 60°C until a constant weight was maintained.

Blood was collected in yr 2 only, on d 2, 9, and 16 from sentinel steers (n = 3 steers/pen; 21 steers/treatment). Sentinel steers were selected from each pen based on their initial BW. Initial BW was stratified for all steers in each pen and the third, fifth, and seventh ranked steers were selected from odd-numbered pen replicates, while second, sixth, and eighth ranked steers were selected from even-numbered pen replicates. Blood was collected via jugular venipuncture using 18-gauge needles and 10 mL vacuum sealed tubes (Becton Dickinson, Franklin Lakes, NJ). Blood was allowed to clot for 24 h at 4°C then centrifuged at 2000 × *g* and sera was harvested and stored frozen until subsequent metabolite analysis. Sera was analyzed for circulating concentrations of non-esterified fatty acids (**NEFA**) and albumin. Non-esterified fatty acids were quantified using a commercially available colorimetric assay (NEFA-HR(2); Wako Diagnostics, Richmond, VA) which converts NEFA to hydrogen peroxide by action of acyl-CoA synthetase, acyl-CoA oxidase, and peroxidase. Measurements of NEFA were performed in triplicate and the intra- and inter-assay coefficients of variation were 1.4 and 6.6%, respectively. Albumin was measured directly using a commercially available colorimetric assay (QuantiChrom DIAG-250; BioAssay Systems, Hayward, CA) which utilizes bromcresol green. Concentrations of albumin were measured in triplicate and the intra- and inter-assay coefficients of variation were 1.7 and 5.9%, respectively.

Animal performance and diet mixing data were analyzed using the General Linear Model procedure of SAS (SAS Inst. Inc., Cary, NC). Treatment effects were tested with treatment and feedlot location block included in the model and pen was considered to be the experimental unit. All BW except initial BW were shrunk 4%. Blood metabolite data were analyzed specific for repeated measures, with fixed effects of treatment, time, and the treatment × time interaction, and steer serving as the experimental unit.

To evaluate effects of within batch mix variation, each pen was assigned a batch fraction (**BF**) value, i.e. a scale of 0 to 1, with 0 being the beginning of batch offload and 1 being the final portion of batch offload. Batch fraction was calculated to represent from which portion of the batch each pen's allotment of feed was derived. This BF value was used to standardize feed batches manufactured for either 3 or 4 pens. For example, if a pen was the first pen fed out of a 3-pen batch, its feed allotment started at 0 and ended at

0.333, resulting in an average BF of 0.166 and the second pen fed from a 4-pen batch would begin at 0.250 and end at 0.500, resulting in an average BF of 0.375. Effects of within batch variation (to test mixing) were analyzed independent of treatment, with BF serving as a fixed effect. Linear and quadratic effects of within batch mix variations within treatment were tested using equally spaced, polynomial orthogonal contrasts. The REG procedure was used to determine correlations between cumulative ADG, proportion of larger feed particles delivered, and BF. When $P \leq 0.05$, treatment means were separated using the LSMEANS statement with the PDIFF option.

RESULTS AND DISCUSSION

Treatment diets in both years were formulated to be isonitrogenous and isocaloric. Since the oat forage was harvested from the same crop from the same field, similar nutrient composition was assumed for both forage sources during diet formulation. In yr 1, diets were reformulated on d 23 to adjust for decreasing CP concentration of oat silage (Table 2.2). Despite this decrease in CP concentration, diet CP concentration from 3 to 22 d was not different ($P = 0.20$). In yr 2, DM inclusion of oat forage was slightly less but CP concentration was increased compared to yr 1.

Year 1

During the initial 2 wk after arrival to the RNC, feed deliveries were managed to accommodate newly-weaned calves by setting upper limits of allowable DMI. Briefly, cattle were allowed approximately 1-times maintenance energy intake (NASEM, 2016) on the first day milled feed was offered and increases in feed offering were such that cattle were not allowed to surpass 2.3-times maintenance energy intake by d 14. In yr 1, we overestimated the DM content of the oat silage at the time of diet formulation. As a consequence, we misunderstood early actual DM offered to the SIL calves which resulted in lesser DMI for the 1-16 d period of the SIL treatment (Table 2.3; $P \leq 0.01$). However, day 1-16 average daily gain (**ADG**) and gain:feed (**G:F**) were unaffected ($P \geq 0.16$) by treatment despite reduced DMI by SIL cattle. From d 17 to the end of the study, SIL cattle had greater DMI ($P \leq 0.01$) and ADG ($P = 0.03$) than HAY or HAYW cattle. Cumulatively in yr 1, SIL- and HAYW-fed cattle had greater DMI than HAY cattle ($P = 0.02$), despite the fact that SIL-fed cattle were initially underfed. Moreover, no cumulative differences in ADG or G:F were observed among dietary treatments ($P \geq 0.24$).

Year 2

In yr 2, SIL-fed cattle had 2-fold greater ADG than either HAY or HAYW cattle during the first 14 d post-receiving period ($P = 0.01$; Table 2.4). This, in combination with no difference in DMI ($P = 0.18$), resulted in greater G:F for SIL-fed cattle compared to HAY or HAYW ($P = 0.01$). However, from d 15 to the termination of the study, HAYW cattle had greater ADG than SIL cattle, with HAY cattle being intermediate ($P = 0.01$). During this time DMI was increased for both HAY and HAYW cattle ($P < 0.01$), yielding G:F that did not differ among the treatments ($P = 0.73$). Cumulatively, from d 1 to 42, no difference in ADG was observed ($P = 0.21$) while SIL-fed cattle had lesser DMI ($P < 0.01$); thus, SIL-fed cattle had a 13% increase in G:F compared to HAY and HAYW cattle ($P = 0.01$).

Little data exists regarding the use of the same crop harvested in both its dry and ensiled forms in receiving-cattle diets. When growing steers were fed dry or ensiled alfalfa, Merchen et al. (1986) reported silage-fed steers had increased ADG and numeric improvements in G:F compared to hay-fed cattle. Additionally, steers grown for 196 d on a grass silage-based diet consumed less DM but with no difference in ADG compared to grass hay-fed cattle (Petit and Flipot, 1992b), despite the similar DM digestibilities (Petit and Flipot, 1992a). Conversely, Dennis et al. (2012) fed growing heifers grass harvested as either dry hay or baleage (high-moisture baled and stretch-wrapped grass hay) and reported hay-fed heifers had 13% and 5% increases in ADG and DMI, respectively with a tendency for increased G:F compared to baleage-fed heifers. Verbič et al. (1999) reported that microbial protein supply per unit of DMI was greater in sheep fed grass hay compared to grass silage. This may be a result of a greater amount of fermentation end-products (i.e. organic acids) in grass silage from the ensiling process which would not contribute as a source of energy for rumen microbes and may explain increases in ADG for hay- vs. silage-fed animals. Lack of differences in the current study, taken together with conflicting reports from the available literature indicate that ensiled forages may serve as suitable substitutes for dried hays of a similar crop in receiving-calf diets.

Although they are not from the same crop, corn silage and alfalfa hay are commonly compared in receiving experiments as they are the primary roughage sources used by feedlot nutritionists in receiving diets (Galyean and Gleghorn, 2001; Vasconcelos and Galyean, 2007; Samuelson et al., 2016). Davis and Caley (1976) fed newly-received steers either corn silage- or alfalfa hay-based receiving diets and observed greater ADG for corn silage-fed steers during the first 2 wk, and throughout the 35-d study.

Additionally, corn silage-fed cattle had increased DMI and greater G:F than cattle fed alfalfa hay (Davis and Caley, 1976). Preston and Kunkle (1974) received steers on either chopped grass hay- or corn silage-based diets and found that hay-fed cattle gained 38% faster than silage-fed cattle during the initial 12 d; however, by the end of the 33-d study any previous differences were negated and similar ADG was observed for both groups of steers, although silage-fed steers had a greater G:F. It should be noted that the grain content of corn silage makes it a more energy dense feedstuff compared to alfalfa hay. Nonetheless, it appears that silages can be used in receiving diets without adverse effects on performance compared to receiving diets with dried hays.

No diet × day interactions were observed for sera metabolite data ($P \geq 0.51$; Table 2.5). Sera concentrations of NEFA were greater on d 2 than d 9 and 16 ($P < 0.01$) which was expected of calves that had been weaned on the truck and transported 580 km. These results are in agreement with results from Knowles et al. (1999) and Marques et al. (2012) who observed greater NEFA concentrations in newly-received cattle following transportation. Increased circulating NEFA on d 2 suggests that these cattle were responding to stresses of transportation and depressed caloric intake during this initial receiving phase. Increases in DMI and a more positive energy balance by d 9 and 16 may explain decreases in NEFA concentrations at these time points. In the current study, initial sera NEFA concentrations following entry into the feedlot were greater than cattle from the same sources previously received to the RNC on oat forage-based diets (Mueller et al., 2011). However, amount of time post-weaning can affect NEFA concentrations, and a significant proportion of those calves were weaned before shipping, contrary to the present study where calves were weaned on the truck. Cattle fed HAY tended to have higher sera concentrations of NEFA compared to cattle fed HAYW or SIL (*P* = 0.09), thus indicating that HAY-fed cattle tended to require greater mobilization of body energy stores during the initial days of the receiving phase. No effect of forage source (*P* = 0.50) or day (*P* = 0.31) was observed on sera concentrations of albumin, which can serve as an indicator of protein status in cattle (Payne et al., 1970; Moriel and Arthington, 2013). Blood concentrations of albumin and total protein can spike well above baseline levels following transportation, but return near to baseline levels within 48 h (Knowles et al., 1999), which would be near to the first time point at which we measured albumin concentrations in the current study. Therefore, these calves most likely returned to normal albumin concentrations prior to our blood collection and this might explain why no effect of time was detected. Potentially, SIL-based receiving diets can reduce the extent of energy mobilization post-weaning compared to HAY.

Bunk sampling

At the time of delivery during yr 1, the SIL diet contained a greater proportion of larger particles compared to the HAY diet (*P* < 0.01; Table 2.6), with the HAYW diet being intermediate. Even though SIL was processed to a shorter length (1.9 vs. 8.9 cm), the difference in larger particles may have been caused by the increased moisture in SIL and HAYW diets, in that a greater amount of fines could adhere to larger particles in the diets with more water. After cattle had consumed about 75% of their feed delivery, the proportion of larger particles remaining in the bunks was not different across treatments (*P* = 0.47). The percentage change in the proportion of large particles from delivery to 75% consumption (i.e. effect of sorting) was nearly 4-fold greater (*P* = 0.04) for HAY compared to SIL. However, the proportion of total DM consumed at post-meal sample collection was greater for HAY (*P* = 0.01), and it is possible that differences in the proportion of DM consumed at post-meal sample collection could have influenced the proportion of larger particles remaining in the bunk.

The proportion of larger particles delivered to the bunk in yr 2 did not differ for both HAY- and SIL-fed cattle but was less than HAYW-fed cattle (*P* = 0.01; Table 2.7). After 75% of delivered feed was consumed, HAY and HAYW bunks contained nearly 2-fold greater proportions of larger particles compared to SIL (*P* = 0.01). Consequently, the percentage change in the proportion of larger particles from delivery to 75% consumption was over 3.5-fold greater for HAY compared to SIL (*P* = 0.05). Using this metric, it appears that using SIL in receiving diets can improve the integrity and stability of the diet mix and apparently reduce the degree to which cattle can physically sort smaller and larger particles in the bunk. Indeed, similar reductions in sorting have been reported in dairy cattle diets, when alfalfa silage replaced alfalfa hay (Leonardi and Armentano, 2003). Using silage rather than dry hays in receiving-calf diets may help provide a more consistent supply of nutrients to each individual animal within the pen by improving mixing integrity and reducing diet sorting.

Not only were we interested in measuring the effects of different roughage sources on diet integrity, but also the effect they have on mixing quality within a batch of feed. In yr 1, each batch of feed was prepared for 3 pens of cattle. In yr 2, cattle were fed from either 3- or 4-pen batches. To account for differences in batch size, each pen was assigned a BF value on a scale of 0 to 1 representing order of batch delivery, with 0 being the beginning of batch offload and 1 being the final portion of batch offload. Batch fraction represents from which portion of the batch each pen's allotment of feed was derived. The proportion of larger particles in delivered feed tended (*P* = 0.08; Table 2.8) to linearly increase with BF (i.e. as the batch was offloaded) in the HAY diet from 11.1% to 20.1%. Similarly, the proportion of larger particles in the HAYW diet increased linearly with BF from 15.6% to 28.0% (*P* = 0.01). The larger particle proportion also tended to increase with BF in the SIL diet (*P* = 0.07) but at a lesser magnitude, from 21.5% to 28.9%. It is important to note that these changes in diet composition from initial to final feed offload were unexpected as these changes were not recognizable upon visual appraisal of the diets. Post-meal proportions of larger particles were also linearly increased with BF in the HAY (*P* = 0.08) and HAYW (*P* = 0.01) treatments but not in the SIL treatment (*P* = 0.25).

We combined data from yr 1 and yr 2 together and regressed the proportion of larger particles delivered to the bunk against BF. We found that as BF increased (i.e. as the batch was offloaded) the proportion of larger particles being delivered also increased (*P* < 0.01; Figure 2.1). Ideally, the proportion of larger particles would be similar throughout batch offload. It appears that we were not achieving optimal mixing conditions to provide uniform particle distribution throughout the batch. Conversely, cumulative ADG linearly decreased (*P* < 0.01; Figure 2.1) as BF increased. Using the proportion of larger particles as a proxy for the proportion of roughage in the ration, it follows that as proportionally more roughage was offloaded later in the batch, the diet energy density would concomitantly decrease, thus the performance of those cattle would be less than those fed early in the batch. Indeed, Hales et al. (2014) reported steers retain greater amounts of energy as the proportion of dietary roughage decreased from 14 to 2%

of total diet DM. It appears that variations in diet mixing that are not recognizable by visual appraisal can impact cattle performance. Additionally, when we regress cumulative ADG of all pens of cattle in both years against the proportion of larger particles delivered to the bunk, we find that cumulative ADG is negatively correlated ($P < 0.01$; $r^2 = 0.37$; Figure 2.2) with increasing proportion of larger particles.

In conclusion, cumulative calf performance was generally unaffected by roughage source except for increased G:F for silage-fed calves in yr 2. Receiving diets containing silage reduced the extent of sorting from the time feed was delivered until approximately 75% of feed was consumed. Changes in the proportion of larger and smaller particles were detected from the beginning to the end of batch offload, despite being unnoticeable upon visual appraisal and these variations in diet mixing across a batch can impact cattle performance. Additionally, silage-based receiving diets may reduce the degree to which receiving calves mobilize body stores of energy compared to HAY-based diets. Generally, adding water to the dry hay was intermediate to HAY and SIL with regards to animal growth performance and diet mixing and integrity characteristics. The observations from this study indicate that SIL is an acceptable substitute for HAY in receiving diets.

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Table 2.1. Comparison of parameters in 2-yr receiving study

Item,	Year 1	Year 2
Initial access to long-stem grass hay, d	1 to 3	1 to 2
First access to milled feed, d	3	2
Interim weight capture, d	16	14
Bunk sample collection, d	32 (all pens)	22 and 30 (replicates 1-3) 24 and 29 (replicates 4-7)
Total length of experiment, d	42	42

Table 2.2. Diet formulations and composition for receiving calves as derived from weekly assays and batching formulas[1]

	Diet[2]		
Item, %	HAY	HAYW	SIL
Year 1			
3-22 d			
Soybean hulls	53.55	53.55	58.70
Oat hay	41.22	41.22	--
Oat silage	--	--	35.57
Supplement[3]	5.24	5.23	5.73
Dry matter	85.97	78.15	48.27
Crude protein	11.70	11.70	11.11
Neutral detergent fiber	64.23	64.23	63.58
Acid detergent fiber	47.66	47.66	48.18
Ash	8.22	8.22	8.00
Net energy for gain, Mcal/kg[4]	1.11	1.11	1.15
23-42 d			
Soybean hulls	51.39	51.39	47.27
Oat hay	40.33	40.33	--
Oat silage	--	--	43.32
Soybean meal	3.05	3.05	4.43
Supplement[3]	5.24	5.24	4.98
Dry matter	84.59	76.90	44.49
Crude protein	13.04	13.04	12.85
Neutral detergent fiber	62.27	62.27	61.19
Acid detergent fiber	45.37	45.37	44.79
Ash	7.97	7.97	8.16
Net energy for gain, Mcal/kg[4]	1.11	1.11	1.09
Year 2			
1-42 d			
Soybean hulls	49.76	49.76	50.17
Oat hay	40.51	40.51	--
Oat silage	--	--	40.02
Dried distillers grains	5.71	5.71	5.76
Supplement[3]	4.02	4.02	4.06
Dry matter	88.35	80.32	51.41
Crude protein	13.16	13.16	13.20
Neutral detergent fiber	58.55	58.55	58.50
Acid detergent fiber	39.15	39.15	39.63
Ash	7.23	7.23	7.58
Net energy for gain, Mcal/kg[4]	1.11	1.11	1.12

[1]All values except dry matter reported on a dry-matter basis.
[2]Roughage source in receiving diets consisted of either oat hay (**HAY**) oat hay with added water (**HAYW**), or oat silage (**SIL**).
[3]Soybean hull-based supplement contained monensin and provided minerals and vitamins to exceed requirements of growing steers.
[4]Based upon tabular feed values (Preston, 2016).

Table 2.3. Performance of calves fed receiving diets with different roughage sources (Year 1)[1]

Item[3],	Diet[2] HAY	HAYW	SIL	SEM	*P*-value
Initial BW, kg	283	283	283	0.2	0.71
d 1-16					
d 16 BW, kg	293	294	291	0.9	0.21
ADG, kg	0.59	0.64	0.48	0.055	0.16
DMI, kg	4.06[a]	4.11[a]	3.63[b]	0.026	< 0.01
G:F	0.145	0.155	0.132	0.0134	0.50
d 17-42					
d 42 BW, kg	316	317	319	1.0	0.25
ADG, kg	0.90[a]	0.90[a]	1.06[b]	0.042	0.03
DMI, kg	6.15[a]	6.39[b]	6.72[c]	0.059	< 0.01
G:F	0.147	0.142	0.158	0.0064	0.24
d 1-42					
ADG, kg	0.78	0.80	0.84	0.022	0.24
DMI, kg	5.36[a]	5.52[b]	5.55[b]	0.042	0.02
G:F	0.146	0.145	0.151	0.0036	0.47

[1]All body weights except initial body weight shrunk 4%.

[2]Roughage source in receiving diets consisted of either oat hay (**HAY**) oat hay with added water (**HAYW**), or oat silage (**SIL**).

[3]BW = body weight; ADG = average daily gain; DMI = dry matter intake; G:F = gain:feed.

[abc]Means without similar superscripts differ ($P \leq 0.05$)

Table 2.4. Performance of calves fed receiving diets with different roughage sources (Year 2)[1]

	Diet[2]				
Item[3]	HAY	HAYW	SIL	SEM	*P*-value
Initial BW, kg	277	277	277	0.04	0.40
d 1-14					
d 14 BW, kg	282[a]	282[a]	287[b]	1.1	0.01
ADG, kg	0.33[a]	0.35[a]	0.71[b]	0.075	0.01
DMI, kg	4.14	4.18	4.13	0.020	0.18
G:F	0.079[a]	0.084[a]	0.172[b]	0.0183	0.01
d 15-42					
d 42 BW, kg	319	322	322	1.1	0.21
ADG, kg	1.35[ab]	1.41[a]	1.27[b]	0.027	0.01
DMI, kg	7.45[a]	7.64[a]	6.84[b]	0.091	< 0.01
G:F	0.181	0.185	0.185	0.0039	0.73
d 1-42					
ADG, kg	1.01	1.06	1.08	0.027	0.21
DMI, kg	6.34[a]	6.49[a]	5.94[b]	0.064	< 0.01
G:F	0.159[a]	0.163[a]	0.182[b]	0.0049	0.01

[1]All body weights except initial body weight shrunk 4%.
[2]Roughage source in receiving diets consisted of either oat hay (**HAY**) oat hay with added water (**HAYW**), or oat silage (**SIL**).
[3]BW = body weight; ADG = average daily gain; DMI = dry matter intake; G:F = gain:feed.
[ab]Means without similar superscripts differ ($P \leq 0.05$)

Table 2.5. Blood metabolites over time of calves fed diets with different roughage sources (Year 2)

	Diet[1]				*P*-value		
	HAY	HAYW	SIL	SEM	Diet	Day	Diet × Day
Day	**Non-esterified fatty acids, mmol**						
2	0.65	0.60	0.58				
9	0.31	0.30	0.29	0.020	0.09	< 0.01	0.51
16	0.34	0.31	0.33				
	Albumin, g/dL						
2	2.97	3.08	2.98				
9	2.94	3.12	2.87	0.125	0.50	0.31	0.87
16	3.09	3.13	3.16				

[1]Roughage source in receiving diets consisted of either oat hay (**HAY**) oat hay with added water (**HAYW**), or oat silage (**SIL**).

Table 2.6. Effect of roughage source and added water on feed particles passing through a 12.7 mm screen on d 32 afternoon feed delivery (Year 1)

	Diet[1]				
Item, % of total	HAY	HAYW	SIL	SEM	*P*-value
Larger particles[2]					
At delivery[3], %	16.9[a]	21.1[b]	26.0[c]	1.21	< 0.01
Post-meal[3], %	38.0	40.0	33.7	3.57	0.47
Change, %	123.3[a]	86.3[ab]	31.6[b]	21.16	0.04
DM consumed[4], %	81.6[a]	77.3[ab]	69.3[b]	2.26	0.01

[1]Roughage source in receiving diets consisted of either oat hay (**HAY**) oat hay with added water (**HAYW**), or oat silage (**SIL**).
[2]Larger particles = feed particles that are retained in a 12.7 mm screen.
[3]% of total dry matter (**DM**).
[4]Percent of DM offering that was consumed at post-meal bunk sample collection.
[abc]Means without similar superscripts differ ($P < 0.05$).

Table 2.7. Effect of roughage source and added water on feed particles passing through a 12.7 mm screen (Year 2)

	Diet[1]				
Item, % of total	HAY	HAYW	SIL	SEM	*P*-value
Larger particles[2]					
At delivery[3], %	12.72[a]	15.64[b]	12.68[a]	0.710	0.01
Post-meal[3], %	35.78[a]	40.30[a]	19.07[b]	4.631	0.01
Change, %	191.5[a]	164.6[ab]	52.7[b]	40.57	0.05
DM consumed[4], %	75.38	74.67	70.79	2.926	0.50

[1]Roughage source in receiving diets consisted of either oat hay (**HAY**) oat hay with added water (**HAYW**), or oat silage (**SIL**).
[2]Larger particles = feed particles that are retained in a 12.7 mm screen.
[3]% of total dry matter (**DM**).
[4]Percent of DM offering that was consumed at post-meal bunk sample collection.
[ab]Means without similar superscripts differ ($P < 0.05$).

Table 2.8. Influence of diet and load distribution on feed particles passing through a 12.7 mm screen (Year 1)

	Batch fraction[1]				*P*-value	
Item	0.166	0.500	0.833	SEM	Linear	Quadratic
HAY[2]						
n	2	2	2			
Larger particles[3]						
At delivery[4], %	11.09	19.46	20.10	2.504	0.08	0.30
Post-meal[4], %	24.35	40.37	49.19	6.719	0.08	0.69
Change, %	114.2	107.6	148.1	40.97	0.60	0.67
HAYW[2]						
n	2	2	2			
Larger particles[3]						
At delivery[4], %	15.55	19.66	27.95	1.542	0.01	0.35
Post-meal[4], %	21.26	42.75	56.01	4.495	0.01	0.51
Change, %	35.3	123.0	100.6	33.52	0.26	0.27
SIL[2]						
n	2	2	2			
Larger particles[3]						
At delivery[4], %	21.50	27.57	28.94	1.898	0.07	0.39
Post-meal[4], %	26.69	36.91	37.52	5.435	0.25	0.52
Change, %	28.9	35.8	30.1	31.09	0.98	0.88

[1]Batch fraction: scale of 0 to 1 to represent which portion of the batch each pen's allotment of feed was derived. 0.166 = first pen delivered out of 3-pen batch; 0.500 = second pen delivered out of 3-pen batch; 0.833 = third pen delivered out of 3-pen batch.

[2]Roughage source in receiving diets consisted of either oat hay (**HAY**) oat hay with added water (**HAYW**), or oat silage (**SIL**).

[3]Larger particles = feed particles that are retained in a 12.7 mm screen.

[4]% of total dry matter.

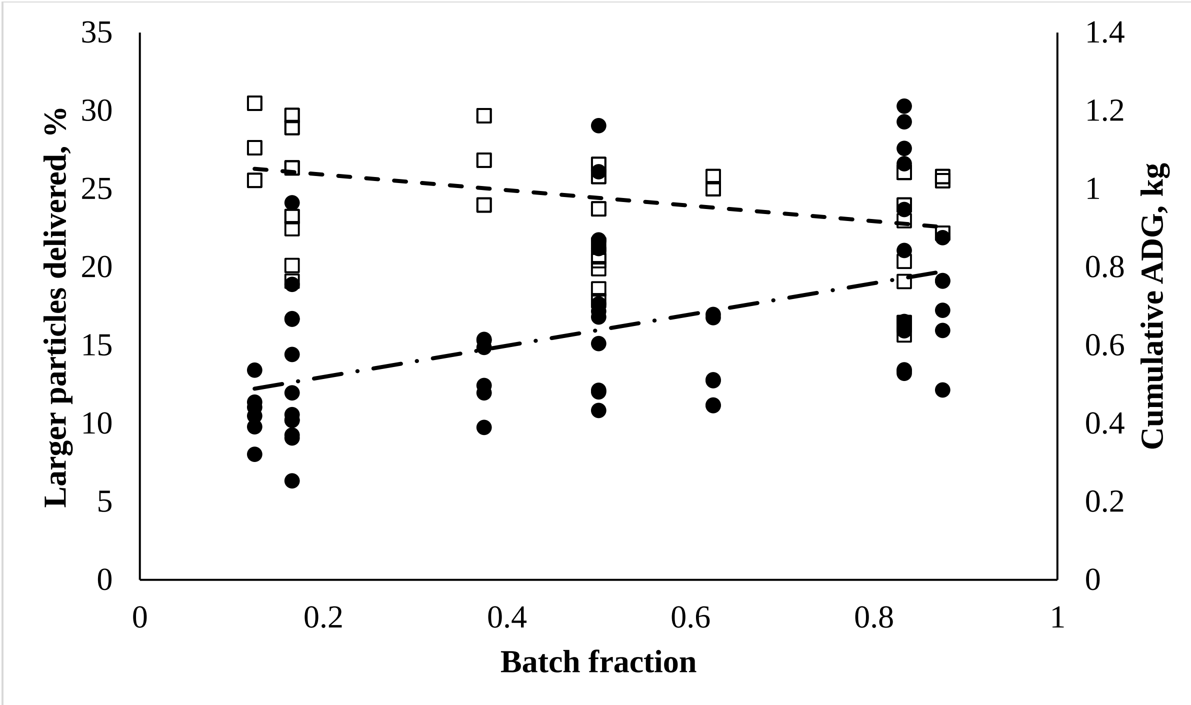

Figure 2.1. The effect of batch fraction on the proportion of larger particles delivered to the bunk and cumulative steer average daily gain (**ADG**). Batch fraction = scale of 0 to 1 to represent which portion of the batch each pen's allotment of feed was derived. Larger particles delivered, % (•; – · –) = 9.9958(BF) + 10.974; r^2 = 0.23. Cumulative ADG (☐; - - -) = -0.1986(BF) + 1.0763; r^2 = 0.15.

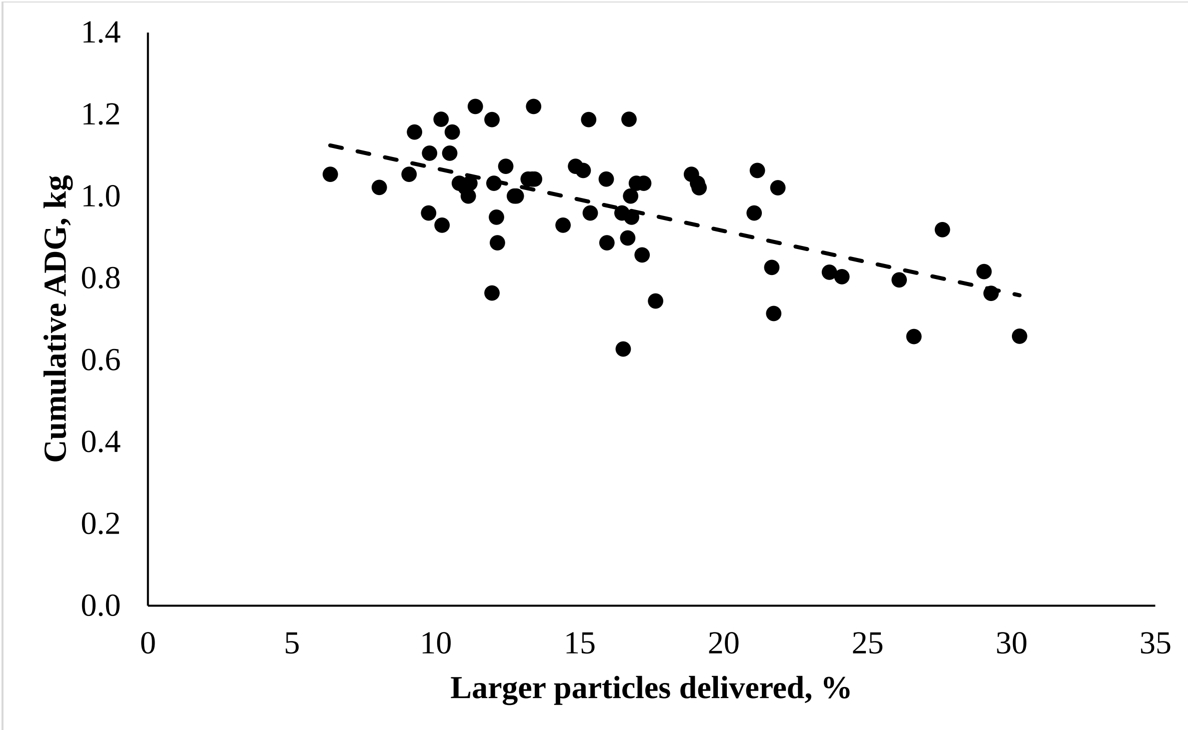

Figure 2.2. Effect of the proportion of larger particles delivered to the bunk on cumulative average daily gain (ADG; yr 1 and 2 data combined). Cumulative ADG = -0.0153(Larger particles delivered) + 1.2211; $r^2 = 0.37$.

CHAPTER THREE:

EFFECTS OF BACKGROUNDING-PHASE RATE OF GAIN ON PERFORMANCE AND CARCASS CHARACTERISTICS OF FEEDLOT STEERS

ABSTRACT

Effects of varying backgrounding phase growth rate (**BGR**) on subsequent finishing phase performance and carcass characteristics were evaluated in 2 experiments. In Exp. 1, 240 steers were randomly assigned to 1 of 3 BGR treatments from study initiation to 397 kg body weight (**BW**): 0.91 kg/d (**LOW**), 1.13 kg/d (**MID**), or 1.36 kg/d (**HIGH**). Net energy equations were used to prescribe sufficient dry matter (**DM**) to achieve the BGR for each group. When each treatment reached the target BW of the backgrounding phase, steers were transitioned to a finishing diet. From this point on, treatments were managed similarly. Steers within each treatment were harvested independently at a common 12th-rib fat endpoint. By design, backgrounding phase average daily gain (**ADG**) linearly increased ($P < 0.01$). The backgrounding phase lasted 92, 78, and 62 d for LOW, MID, and HIGH, respectively. Finishing phase ADG and DM intake (**DMI**) were linearly decreased with greater BGR ($P < 0.01$), but no difference in gain:feed (**G:F**) was observed ($P \geq 0.35$). Cumulatively, ADG linearly increased with greater BGR ($P < 0.01$), but G:F was not different ($P \geq 0.17$). Hot carcass weight (**HCW**) decreased linearly with greater BGR ($P < 0.01$). Marbling score responded quadratically as it increased from LOW to MID, then decreased thereafter ($P = 0.02$). In Exp. 2, 144 steers were randomly assigned to the same 3 treatments used in Exp. 1. Backgrounding phase endpoint BW was 408 kg in Exp. 2. As expected, backgrounding phase ADG linearly increased ($P < 0.01$). The backgrounding phase lasted 76, 61, and 54 d for LOW, MID, and HIGH, respectively. Finishing phase ADG and DMI linearly decreased ($P \leq 0.02$) as BGR increased, with no difference in G:F ($P \geq 0.16$). Cumulative ADG linearly increased with greater BGR ($P = 0.02$) while G:F also tended to increase ($P = 0.07$).

Restricting BGR linearly increased HCW (*P* = 0.04). Similar to Exp. 1, marbling score tended to respond quadratically to increasing BGR as it increased from LOW to MID, then decreased between MID and HIGH (*P* = 0.06). When regressing marbling scores from Exp. 1 and 2 on BGR, we found that marbling responded quadratically (*P* = 0.03) and BGR accounted for approximately 8% of the variation in marbling score. Restricting BGR can result in improved finishing phase performance and greater final BW; however, a greater number of days on feed is required. Increases in HCW can also be achieved with lesser BGR, although optimum carcass quality may be realized with only modest restriction in BGR.

INTRODUCTION

Backgrounding calves after weaning and prior to entry into the feedlot is a common practice in the cattle feeding industry. A common quality of backgrounding programs is feeding to maintain a less than maximal growth rate in order to suppress lipid deposition and promote maturation of lean tissue and bone (Block et al., 2001). Goals of the backgrounding phase include allowing smaller-framed cattle to reach a greater (more desirable) body weight (**BW**) at a similar body fat endpoint (Byers, 1982), to increase mature size (Owens et al., 1993), meet a targeted average daily gain (**ADG**), offer a market outlet for forages (Sip and Pritchard, 1991), and shift the timing and quantity of cattle entering the feedlot (Peel, 2003). Limiting backgrounding growth rate (**BGR**) is typically accomplished by either reducing the energy content of the diet by the inclusion of roughages, or by limit feeding a high-concentrate diet. Using the net energy equations to determine the quantities of feed required to meet a specified BGR may allow for more precise management of cattle prior to the finishing phase in order to reach the goals previously described. The objective of this research was to determine the effect of differing programmed rates of gain during the backgrounding phase on subsequent finishing phase performance and carcass characteristics.

MATERIALS AND METHODS

All experimental protocols were approved by the SDSU Institutional Animal Care and Use Committee (approval # 13-088E and 18-004E). These experiments were conducted at the South Dakota State University (**SDSU**) Ruminant Nutrition Center (**RNC**).

Experiment 1

Angus and Angus-based crossbred steer calves (n = 240) sourced from 2 western South Dakota ranches were used to determine the effects of 3 different BGR on finishing phase performance and carcass characteristics. Steers were blocked by ranch of origin, stratified by BW and randomly assigned to treatment and then to pen replicate (8 steers/pen; 10 pen replicates/treatment). Six pen replicates per treatment from one source were started on the experiment on November 19, 2013, and 4 pen replicates per treatment from the second source were started on the experiment 6 d later on November 25, 2013. Experimental d 1 corresponds to the day each block was started on the experiment. Treatments consisted of 3 different BGR, 0.91 (**LOW**), 1.13 (**MID**), or 1.36 kg/d (**HIGH**) which were achieved using prescribed offerings of a common sorghum silage-based diet (Table 3.1). Prescribed dry matter (**DM**) offerings were determined using net energy equations (NRC, 1984). The ionophore, vitamin, and mineral concentration of the supplement was adjusted for each treatment to maintain similar intakes of these ingredients despite differences in total DM intake (**DMI**). Cattle were implanted with 200 mg progesterone and 20 mg estradiol benzoate (Synovex S; Zoetis, Kalamazoo, MI) on d 1. Cattle were vaccinated against clostridial diseases on December 13 and 17 (Alpha 7; Boehringer Ingelheim, Duluth, Georgia). Twice during the backgrounding phase diets were reformulated to allow for evolving feedstuff inventories, as reported in Table 3.1. Cattle were fed twice daily, and feed deliveries were programmed to achieve the caloric intake necessary to support the BGR of each treatment. Cattle were weighed approximately every 21 d to ensure cattle were achieving targeted BGR. Treatments were applied from initiation of the study until average BW within each treatment reached 397 kg, at which point the backgrounding phase ended. Upon completion of the backgrounding phase, cattle were placed on a transition diet for 7 d followed by a common finishing diet for the remainder of the study (Table 3.1). After 14 d on the finishing diet, steers were reimplanted with 120 mg trenbolone acetate and 24 mg of estradiol (Revalor-S; Merck Animal Health, Madison, NJ). The finishing diets was reformulated once to allow for evolving feedstuff inventory (Table 3.1). Steers were harvested, as a treatment, when the average backfat of the treatment was determined by visual appraisal to be 1.4 cm.

Experiment 2

Similar to Exp. 1, Angus and Angus-based crossbred steer calves (n = 144) were sourced from 2 western South Dakota ranches for this experiment. Steers were blocked by ranch of origin, stratified by BW, and randomly assigned to 1 of 3 treatments and then pen replicate (8 steers/pen; 6 pen replicates/treatment). All steers were started on the experiment on December 6, 2017. Treatments in this experiment were the same as those used in Exp. 1. Corn silage-based diets were used to achieve targeted BGR (Table 3.2). Prescribed DM offerings were determined using net energy equations (NRC, 1984). The ionophore, vitamin, and mineral concentration of the supplement was adjusted for each treatment to maintain similar intakes of these ingredients despite differences in total daily feed intake. Steers were vaccinated with clostridium perfringens type A toxoid (Elanco; Greenfield, IN) and implanted with 100 mg progesterone and 10 mg estradiol benzoate (Synovex C; Zoetis) on d 1. On d 43, steers were treated for internal and external parasites (Cydectin, Bayer, Shawnee, KS), and on d 71 steers were treated for external parasites (CyLence; Bayer). Steers were weighed approximately every 21 d to ensure steers were achieving targeted BGR. Treatments were applied from initiation of the study until each treatment reached 408 kg BW, at which point the backgrounding phase ended. Upon completion of the backgrounding phase, cattle were placed on a transition diet for 7 d followed by a common finishing diet for the remainder of the study (Table 3.2). After 14 d on the finishing diet, each treatment was reimplanted with 120 mg trenbolone acetate and 24 mg of estradiol (Revalor-S; Merck Animal Health). Steers were harvested, as a treatment, when the average backfat of the treatment was determined by visual appraisal to be 1.4 cm.

Laboratory analyses

Feed records were compiled weekly and feed batching records and weekly ingredient assay values were used to calculate actual diet formulation and composition values. Feed samples were dried in a forced air oven at 60°C until a constant weight was maintained to determine DM, then ground through a 1 mm screen (Thomas-Wiley Laboratory Mill Model 4, Thomas Scientific USA, Swedesboro, NJ). Ground samples were analyzed for DM (method no. 935.29; AOAC, 2012), crude protein (**CP**; Kjeldahl procedure; method no. 951.01; AOAC , 2012), neutral detergent fiber (**NDF**) and acid detergent fiber (**ADF**; Goering and Van Soest, 1970), and ash content (method no. 942.05; AOAC, 2012).

Statistical analyses

Data from 6 steers from Exp. 1 and 1 steer from Exp. 2 were removed from analyses for reasons unrelated to treatment. Data from these steers were included up to the point that they were realized, but not included in any cumulative performance analyses. Data were analyzed using the General Linear Model procedure of SAS (SAS Inst. Inc., Cary, NC). Treatment effects were tested with treatment and source block in the model and pen was considered to be the experimental unit. All BW except initial BW were shrunk 4%. Carcass-adjusted final BW was calculated by dividing hot carcass weight by a standard dressing percent of 62.5%. Linear and quadratic effects of BGR were tested using equally spaced, polynomial orthogonal contrasts. Marbling score data from both experiments were combined and a quadratic regression of marbling score on BGR was carried out using the PROC REG procedure of SAS (SAS Inst. Inc.) which included experiment in the model and steer served as the experimental unit. Effects were considered significant at P-value of ≤ 0.05, with tendencies declared at P-values between 0.05 and 0.10.

RESULTS

Experiment 1

Animal performance data from Exp. 1 are presented in Table 3.3. Initial BW did not differ among the 3 BGR groups ($P \geq 0.21$). A quadratic response was noted for backgrounding end BW ($P = 0.01$) where ending BW was decreased for the HIGH treatment. As a result of our experimental procedures, backgrounding phase ADG linearly increased ($P < 0.01$). Backgrounding phase DMI linearly increased with increasing BGR ($P < 0.01$). Gain:feed (**G:F**) was unaffected by BGR during the backgrounding phase ($P \geq 0.16$).

Compared to the HIGH group, steers backgrounded at MID and LOW rates took 2 and 5 fewer days on finishing diets to reach their targeted 12th-rib fat endpoint. Limiting BGR linearly increased final weights by 11 kg for MID, and 21 kg for LOW compared to HIGH ($P < 0.01$). During the finishing phase there was a linear decrease in ADG ($P < 0.01$) with increasing BGR with a concomitant decrease in DMI ($P < 0.01$). Similar changes in both ADG and DMI during the finishing phase led to no change in G:F ($P \geq 0.33$). Cumulatively, ADG ($P < 0.01$) and DMI ($P < 0.01$) increased with increasing BGR resulting in no difference in G:F ($P \geq 0.24$). However, the total feeding days were decreased by 11 and 25 d for MID and HIGH, respectively, compared to LOW. On a carcass-adjusted basis, final BW linearly decreased with greater BGR ($P < 0.01$). Carcass adjusted cumulative ADG increased linearly ($P = 0.04$) as BGR increased, but G:F was not different ($P \geq 0.24$).

Carcass data from Exp. 1 are reported in Table 3.4. 12th-rib fat was not different among treatments ($P \geq 0.62$). Similar to final BW, hot carcass weight (**HCW**) linearly decreased ($P < 0.01$) with increasing BGR, thus resulting in a tendency for a quadratic response for dressing percentage ($P \geq 0.08$). Increasing BGR tended to result in a linear decrease in longissimus muscle (**LM**) area; $P = 0.09$). Interestingly, marbling score responded quadratically ($P = 0.02$) to increasing BGR, where marbling score increased from the LOW to MID treatment and decreased thereafter. No difference in yield grade (**YG**) was observed ($P \geq 0.88$), and estimated empty body fat content was not affected by

BGR and averaged approximately 30.8%. When final BW was adjusted to 28% empty body fat, it linearly decreased with increasing BGR (*P* < 0.01).

Experiment 2

Animal performance data from Exp. 2 are presented in Table 3.5. Initial BW did not differ among treatments (*P* ≥ 0.77). Backgrounding phase end BW did not differ (*P* ≥ 0.53). In contrast, backgrounding phase ADG linearly increased with greater BGR (*P* < 0.01). The LOW and MID steers took an additional 22 and 7 d, respectively, to reach their targeted backgrounding ending BW. By design, backgrounding phase DMI linearly increased with BGR (*P* < 0.01), as steers were offered prescribed amounts of DM to achieve the BGR of each treatment. Gain:feed increased linearly with increasing BGR (*P* < 0.01).

The finishing phase in this experiment lasted 112 to 113 d for all treatments. Final BW linearly decreased with increasing BGR (*P* = 0.04). Similarly, ADG (*P* = 0.02) and DMI (*P* = 0.01) linearly decreased during the finishing phase with increasing BGR, thus resulting in no difference in finishing phase G:F (*P* ≥ 0.16).

Cumulatively, MID and HIGH steers spent 14 and 21 less days on feed, respectively, compared to LOW steers. Increasing BGR yielded linear increases in cumulative ADG (*P* = 0.02), while DMI responded quadratically (*P* = 0.03), as DMI increased from the LOW to MID treatment where it reached a plateau. Furthermore, there was a tendency for an linear increase in G:F with greater BGR (*P* = 0.07). Carcass-adjusted final BW linearly decreased with greater BGR (*P* = 0.04), while carcass-adjusted

ADG linearly increased ($P = 0.03$). Carcass-adjusted G:F responded quadratically, where it decreased from LOW to MID and increased from MID to HIGH.

Carcass data from Exp. 2 are reported in Table 3.6. 12th-rib fat was not different among treatments ($P \geq 0.22$). Greater BGR resulted in linear decreases in HCW ($P = 0.04$), but linear increases ($P = 0.04$) in LM area. A quadratic response was observed for dressing percent, where it decreased from the LOW to MID treatment and then increased again from MID to HIGH. No difference in kidney, pelvic, and heart fat was observed ($P \geq 0.46$). Marbling score tended ($P = 0.06$) to respond quadratically to increasing BGR, as it increased from LOW to MID and decreased thereafter. Yield grade responded quadratically ($P = 0.04$), where it decreased from LOW to MID and then plateaued. No differences were observed for estimated empty body fat ($P \geq 0.18$) or BW adjusted to 28% empty body fat ($P \geq 0.37$).

DISCUSSION

While the end backgrounding BW in Exp. 1 for LOW and MID were relatively near to the target, HIGH steers were 18 kg lighter than the target. The target BW for the HIGH steers was collected during blizzard-like conditions and the BW of this group was less than expected. As a consequence, BGR in Exp. 1 was 1.00, 1.14, and 1.21 kg/d for LOW, MID, and HIGH, respectively. It is likely that the BW collected on this day were not reflective of the corresponding treatment, because the steers had been exposed to an extreme weather condition. Our hypothesis is that these steers stood in the blizzard-conditions all night and were extremely cold stressed. Perhaps extreme weather conditions resulted in dehydration as well as depletion of body glycogen stores with associated body water and thus, overall BW for HIGH steers. At previous BW measurements, HIGH steers were within reasonable deviations from the target BW. Each g of body glycogen is typically associated with 3-4 g of water (Pethick et al., 1995); therefore severe glycogen depletion could result in appreciable loss of BW, that could be readily repleted once cold stress was alleviated with no additional feed resources.

In Exp. 2, backgrounding end BW were very near to our targeted BW of 408 kg. While actual BGR was less than targeted for HIGH in Exp. 1, BGR for all 3 groups was greater than targeted values in Exp. 2. Differences in DMI during the backgrounding phase in both experiments were expected since cattle were not allowed to surpass prescribed DM offerings during this period. While no differences in backgrounding phase G:F were observed in Exp. 1, G:F increased 20% with greater BGR in Exp. 2.

While backgrounding cattle at a restricted rate of gain has mixed results on G:F during this phase, greater efficiency is often observed during the subsequent finishing period. Sainz et al. (1995) backgrounded steers from 237 to 327 kg on a high-concentrate diet at either *ad libitum* or limited intake. Cattle fed *ad libitum* had improved G:F during the growing period compared to limit-fed cattle. Conversely, cattle limit-fed during backgrounding were more efficient during the finishing phase compared to cattle backgrounded at *ad libitum* intakes. Cumulatively, no difference in G:F was observed; however, it took nearly 50 additional d for cattle backgrounded at restricted rates to reach a similar final weight (Sainz et al., 1995). Loerch and Fluharty (1998) backgrounded cattle at similar rates of gain to those used in the current study and reported no difference in G:F during the backgrounding phase. Additionally, no difference in finishing or cumulative ADG or G:F was observed when cattle were harvested at similar final weights. Felix et al. (2011) limit-fed cattle to gain either 0.9 or 1.4 kg/d during the backgrounding phase during which no difference in G:F was observed. During the finishing phase, cattle grown more slowly during backgrounding compensated to grow more rapidly and more efficiently during the finishing phase. When harvested at a common end BW, cattle grown at 1.4 kg/d consumed more DM and had a tendency for improved ADG, with no overall difference in G:F (Felix et al., 2011).

Others have used diets with lesser energy content to restrict BGR. Ridenour et al. (1982) backgrounded cattle using diets with either 50 or 85% concentrate and observed greater finishing phase ADG for cattle grown on the 50% concentrate diet with no difference in G:F. Cumulatively, cattle grown on the high-concentrate diet had a small advantage in ADG but no difference in G:F when harvested at a common 12th-rib fat endpoint (Ridenour et al., 1982). Similarly, finishing phase ADG and G:F were improved for cattle backgrounded on a high-concentrate diet compared to cattle backgrounded at a restricted rate on *ad libitum* forage intake (Sainz et al., 1995). Conversely, Loken et al. (2009) varied backgrounding diet energy content to alter BGR, but noted no differences in finishing phase ADG, DMI, or G:F. However, the lack of observed differences by these authors may be because differences in BGR (1.40 vs. 1.67 kg/d) may not have been sufficient enough to elicit a response during the finishing phase. It appears that restricting BGR can result in improvements in finishing phase performance. Indeed, Lancaster et al. (2014) used regression models to evaluate the effect of BGR on finishing phase performance and found that both ADG and G:F during the finishing phase were negatively correlated to BGR. The effect of varying BGR on cumulative growth performance is much less conclusive and is often dependent upon the endpoint criteria selected for the finishing phase, whether it be days on feed or 12th-rib fat thickness.

We targeted a 12th-rib fat endpoint of 1.4 cm for each treatment. Actual 12th-rib fat measures in Exp. 1 (1.38 ± 0.025 cm) were very near to targeted 12th-rib fat endpoint values; however, measures were slightly greater than targeted values in Exp. 2 (1.53 ± 0.032 cm). Hot carcass weight was increased as BGR was restricted in both experiments. When backgrounding ADG was limited with a high-forage diet, Sainz et al. (1995) reported decreased HCW compared to cattle fed a high-concentrate diet throughout. However, when these authors restricted BGR to a similar degree by limit feeding a high-concentrate diet, HCW did not differ from cattle fed a high-concentrate diet ad libitum. Block et al. (2001) backgrounded cattle at a restricted BGR for either 70 or 126 d and reported increases in both final BW and HCW when cattle were grown for 126 d. When cattle backgrounded at different rates of gain are harvested at a common BW endpoint, little difference in HCW is typically observed. Ridenour et al. (1982) observed no difference in HCW when cattle were backgrounded at different rates of gain. When cattle were grown at similar BGR to the ones used in the current study, Loerch and Fluharty (1998) reported no HCW differences. Similarly, Loken et al. (2009) observed no difference in HCW; however, cattle with greater BGR displayed an 11 kg numerical increase in HCW from a relatively small increase (0.27 kg/d) in BGR. It appears that harvest point selection can largely influence whether differences in HCW are elicited from differences in BGR. According to Lancaster et al. (2014), when using compiled available data, HCW was positively correlated with BGR, contrary to the results of the current study.

Longissimus muscle area decreased slightly with greater BGR in Exp. 1; however, the opposite was true in Exp. 2 where an increase in LM area was observed as BGR increased. Similar to HCW, greater BGR has been shown to be positively correlated to LM area (Lancaster et al., 2014). While no differences in YG were observed in Exp. 1, variations in carcass characteristics resulted in decreasing YG with greater BGR in Exp. 2. Similarly, others have reported no change in YG with differences in BGR (Ridenour et al., 1982; Sainz et al., 1995; Loerch and Fluharty, 1998). Although, Felix et al. (2011) reported restricted BGR decreased YG when cattle were finished at a common final BW.

Marbling score is not typically correlated to differences in BGR (Reuter and Beck, 2013; Lancaster et al., 2014). Indeed, Loerch and Fluharty (1998) noted no differences in quality grade when cattle were backgrounded at rates similar to those used in the current study and harvested at a common final BW. However, when marbling scores were adjusted for 12th-rib fat thickness, marbling scores were positively correlated to BGR (Lancaster et al., 2014). Interestingly, we observed a quadratic response in marbling score to increasing BGR as evidenced by the intermediate BGR group yielded the greatest marbling score in both experiments. Perhaps restricting BGR to LOW sufficiently reduced caloric intake to the point where intramuscular fat deposition was suppressed compared to MID. Further, it is possible that greater total days (Exp. 1 = 14 d; Exp. 2 = 7 d) on feed for MID compared to HIGH allowed enough time for MID cattle to deposit greater amounts of intramuscular fat.

When we combine individual animal data from both experiments, we find that the regression of marbling score on actual BGR was quadratic (P = 0.03). This quadratic regression model accounted for approximately 8% of the variation in marbling score. A quadratic response suggests that optimal marbling score may be realized with less than maximal BGR.

In conclusion, restricting rate of gain during the backgrounding phase can improve finishing phase growth rate and gain efficiency. Furthermore, little to no effect on cumulative ADG or G:F were realized when restricting growth rate during the backgrounding phase, although a greater amount of days were required to reach a common 12th-rib fat endpoint. Greater hot carcass weight can be achieved by restricting backgrounding rate of gain, but optimal carcass quality can be achieved with only modest restriction in backgrounding phase growth rate. More research is warranted to better understand how to manage cattle during the backgrounding phase to optimize finishing phase performance and carcass characteristics.

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Table 3.1. Composition of backgrounding, transition, and finishing diets as derived from weekly assays and batching formulas (Exp. 1)[1]

	Backgrounding[2]			Transition	Finishing[3]	
Item, %	1	2	3		1	2
Sorghum silage	40.17	29.11	--	--	--	8.81
Corn silage	--	--	52.50	37.13	12.38	--
Grass hay	--	10.26	9.93	--	--	--
Dry-rolled corn	22.46	22.67	--	45.23	45.41	45.55
High-moisture corn	--	--	--	--	24.62	27.93
Soybean hulls	26.90	27.20	27.36	--	--	--
Dried distillers grains	--	--	--	13.26	13.22	13.36
Pelleted supplement[4]	10.47	10.76	10.21	--	--	--
Liquid supplement[5]	--	--	--	4.38	4.37	4.35
Dry matter	48.00	52.85	56.59	61.07	71.12	67.50
Crude protein	13.08	13.00	11.42	12.51	13.16	13.05
Neutral detergent fiber	44.98	43.54	44.21	23.07	15.79	16.72
Acid detergent fiber	29.79	28.94	28.37	10.85	6.20	7.03
Ash	8.84	8.53	6.84	3.64	3.18	3.47
Net energy for gain, Mcal/kg[6]	1.06	1.06	1.04	1.26	1.40	1.38

[1]All values except dry matter reported on a dry-matter basis.
[2]Backgrounding diet 1 fed from November 19, 2013 to December 17, 2013; backgrounding diet 2 fed from December 18, 2013 to January 10, 2014; backgrounding diet 3 fed from January 10, 2014 through the end of the backgrounding phase.
[3]Finishing diet 1 fed from initiation of finishing diets until May 3, 2014; finishing diet 2 fed from May 4, 2014 until end of the finishing phase.
[4]Soybean meal-based pelleted supplement formulated to provide 28 mg/kg monensin and vitamins and minerals to exceed requirements of growing steers (NASEM, 2016).
[5]Liquid supplement formulated to provide 33 mg/kg monensin and vitamins and minerals to exceed requirements of growing steers (NASEM, 2016).
[6]Predicted from tabular values (Preston, 2016).

Table 3.2. Composition of backgrounding, transition, and finishing diets as derived from weekly assays and batching formulas (Exp. 2)[1]

Item, %	Backgrounding	Transition	Finishing
Corn silage	63.67	24.95	--
Oat hay	15.23	8.98	--
Grass hay	--	--	7.86
Dry-rolled corn	--	26.58	35.67
High-moisture corn	--	20.78	35.16
Dried distillers grains	14.96	13.65	16.23
Pelleted supplement[2]	6.14	--	--
Liquid supplement[3]	--	5.06	5.08
Dry matter	45.52	61.15	78.54
Crude protein	12.81	12.80	13.45
Neutral detergent fiber	34.95	21.86	16.18
Acid detergent fiber	19.06	10.51	6.36
Ash	6.20	5.86	5.20
Net energy for gain, Mcal/kg[4]	1.06	1.25	1.38

[1]All values except dry matter reported on a dry-matter basis.
[2]Pelleted supplement formulated to provide 28 mg/kg monensin and vitamins and minerals to exceed requirements of growing steers (NASEM, 2016).
[3]Liquid supplement formulated to provide 33 mg/kg monensin and vitamins and minerals to exceed requirements of growing steers (NASEM, 2016).
[4]Predicted from tabular values (Preston, 2016).

Table 3.3. Backgrounding, finishing, and cumulative performance of steers grown at varying average daily gain during the backgrounding phase (Exp. 1)[1]

	Backgrounding ADG target[2]				*P*-value	
Item[3],	LOW	MID	HIGH	SEM	Linear	Quadratic
Backgrounding						
Initial BW, kg	303	303	303	0.3	0.93	0.21
End BW, kg	395	392	379	1.4	< 0.01	0.01
ADG, kg	1.00	1.14	1.21	0.019	< 0.01	0.10
DMI, kg	7.47	8.31	9.04	0.033	< 0.01	0.21
G:F	0.133	0.138	0.134	0.0022	0.88	0.16
d	92	78	62	--	--	--
Finishing						
Final BW, kg	607	597	586	3.0	< 0.01	0.79
ADG, kg	1.76	1.66	1.65	0.021	< 0.01	0.10
DMI, kg	11.07	10.47	10.24	0.068	< 0.01	0.04
G:F	0.159	0.159	0.162	0.0019	0.33	0.60
d	120	123	125	--	--	--
Cumulative						
Live basis						
ADG, kg	1.43	1.46	1.50	0.016	< 0.01	0.88
DMI, kg	9.51	9.63	9.84	0.043	< 0.01	0.40
G:F	0.150	0.152	0.153	0.0015	0.24	0.82
d	212	201	187	--	--	--
Carcass-adjusted basis[4]						
Final BW, kg	622	614	596	3.6	< 0.01	0.25
ADG, kg	1.50	1.55	1.56	0.019	0.04	0.44
G:F	0.158	0.161	0.158	0.0017	0.81	0.24

[1]Shrunk (4%) weight basis.
[2]Treatments targeted backgrounding phase ADG of 0.91 (**LOW**), 1.13 (**MID**), or 1.36 kg/d (**HIGH**).
[3]BW = body weight; ADG = average daily gain; DMI = dry matter intake; G:F = gain:feed.
[4]Carcass adjusted final BW = hot carcass weight divided by 0.625.

Table 3.4. Carcass characteristics of steers grown at varying rates of average daily gain during the backgrounding phase (Exp. 1)

	Backgrounding ADG target[1]				*P*-value	
Item[2],	LOW	MID	HIGH	SEM	Linear	Quadratic
HCW, kg	388	384	372	2.3	< 0.01	0.26
DP, %	64.0	64.2	63.6	0.19	0.14	0.08
LMA, sq. cm	83.0	82.6	81.5	0.59	0.09	0.60
12th-rib fat, cm	1.36	1.39	1.39	0.041	0.62	0.75
KPH, %	1.9	1.9	2.0	0.02	0.02	0.08
Marbling score[3]	554	587	569	8.2	0.21	0.02
YG	3.36	3.36	3.35	0.061	0.91	0.88
EBF[4], %	30.6	31.0	30.7	0.24	0.86	0.28
AFBW[5], kg	581	567	560	3.5	< 0.01	0.38

[1]Treatments targeted backgrounding phase ADG of 0.91 (**LOW**), 1.13 (**MID**), or 1.36 kg/d (**HIGH**).
[2]HCW = hot carcass weight; DP = dressing percent; LMA = longissimus muscle area; KPH = kidney, pelvic, and heart fat; YG = calculated USDA yield grade.
[3]Small^{00} = 500.
[4]Estimated empty body fat predicted from carcass measurements (Guiroy et al., 2001).
[5]Adjusted final body weight adjusted to 28% empty body fat (Guiroy et al., 2001).

Table 3.5. Backgrounding, finishing, and cumulative performance of steers grown at varying average daily gain during the backgrounding phase (Exp. 2)[1]

	Backgrounding ADG target[2]					
Item[3],	LOW	MID	HIGH	SEM	Linear	Quadratic
Backgrounding						
Initial BW, kg	333	332	333	0.9	0.95	0.77
End BW, kg	411	411	409	1.4	0.53	0.72
ADG, kg	1.03	1.28	1.42	0.022	< 0.01	0.05
DMI, kg	7.40	8.28	8.52	0.050	< 0.01	< 0.01
G:F	0.139	0.155	0.167	0.0021	< 0.01	0.39
d	76	61	54	--	--	--
Finishing						
Final BW, kg	628	619	612	4.7	0.04	0.93
ADG, kg	1.94	1.85	1.80	0.038	0.02	0.69
DMI, kg	12.04	11.81	11.44	0.119	0.01	0.64
G:F	0.161	0.156	0.157	0.0020	0.16	0.29
d	112	113	113	--	--	--
Cumulative						
Live basis						
ADG, kg	1.57	1.65	1.67	0.028	0.02	0.43
DMI, kg	10.16	10.57	10.50	0.080	0.01	0.03
G:F	0.154	0.156	0.159	0.0018	0.07	0.68
d	188	174	167	--	--	--
Carcass-adjusted basis[4]						
Final BW, kg	639	620	623	4.9	0.04	0.09
ADG, kg	1.63	1.65	1.74	0.029	0.03	0.37
G:F	0.161	0.156	0.166	0.0023	0.14	0.03

[1]Shrunk (4%) weight basis

[2]Treatments targeted backgrounding phase ADG of 0.91 (**LOW**), 1.13 (**MID**), or 1.36 kg/d (**HIGH**).

[3]BW = body weight; ADG = average daily gain; DMI = dry matter intake; G:F = gain:feed.

[4]Carcass adjusted final BW = hot carcass weight divided by 0.625.

Table 3.6. Carcass characteristics of steers grown at varying rates of average daily gain during the backgrounding phase (Exp. 2)

	Backgrounding ADG target[1]					
Item[2],	LOW	MID	HIGH	SEM	Linear	Quadratic
HCW, kg	400	387	390	3.1	0.04	0.08
DP, %	63.7	62.5	63.6	0.39	0.93	0.04
LMA, sq. cm	85.4	89.2	88.6	0.97	0.04	0.09
12th-rib fat, cm	1.59	1.47	1.52	0.051	0.32	0.22
KPH, %	1.87	1.89	1.89	0.015	0.49	0.46
Marbling score[3]	592	642	598	18.2	0.83	0.06
YG	3.55	3.15	3.24	0.085	0.03	0.04
EBF[4], %	32.1	31.4	31.3	0.354	0.18	0.53
AFBW[5], kg	561	554	558	5.3	0.66	0.37

[1]Treatments targeted backgrounding phase ADG of 0.91 (**LOW**), 1.13 (**MID**), or 1.36 kg/d (**HIGH**).
[2]HCW = hot carcass weight; DP = dressing percent; LMA = longissimus muscle area; KPH = kidney, pelvic, and heart fat; YG = calculated USDA yield grade.
[3]Small^{00} = 500.
[4]Estimated empty body fat predicted from carcass measurements (Guiroy et al., 2001).
[5]Adjusted final body weight adjusted to 28% empty body fat (Guiroy et al., 2001).