Reduced supplementation frequency increased insulin-like growth factor 1 in beef steers fed medium quality hay and supplemented with a soybean hull and corn gluten feed blend

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ABSTRACT: Reducing supplementation frequency in calf growing programs can reduce labor and equipment operation costs. However, little is understood about the metabolic response of ruminants to large fluctuations in nutrient intake. Eighteen Angus or Angus × Simmental cross steers (287 ± 20 kg and 310 ± 3.6 d of age) were individually fed 1 of 3 dietary treatments using Calan gates. Dietary treatments consisted of ad libitum hay and no supplement (NS), ad libitum hay and 1% BW (as-fed basis) of supplement daily (DS), or ad libitum hay and 2% BW (as-fed basis) of supplement every other day (SA). The supplement was 90% DM and contained (as-fed basis) 47% corn gluten feed, 47% soybean hulls, 2% feed grade limestone, and 4% molasses. Hay intake and ADG was measured over a 52-d period. Steers were then moved to individual tie stalls. Steers were fed at 0800 h and blood samples were collected every hour from 0600 to 1400 h and at 1800, 2200, and 0200 h over a 2-d period. Gains were increased (P < 0.01) by supplementation but did not differ (P = 0.68) due to supplementation frequency. Average daily gain was 0.45, 0.90, and 0.87 kg ·hd⁻¹·d⁻¹ (SEM ± 0.05) for steers NS, DS, and SA, respectively. Across the 2-d supplementation cycle area under the concentration time curve (AUC) for plasma glucose was increased (P < 0.01) by supplementation but did not differ (P = 0.41) due to supplementation frequency. The AUC for plasma insulin was increased by supplementation (P < 0.01) but did not differ (P = 0.67) due to supplementation frequency. Plasma IGF-1 was increased (P = 0.01) by supplementation and was greater (P = 0.04) for steers supplemented SA than DS. Gains of steers supplemented with a soybean hull and corn gluten feed blend on alternate days did not differ from those supplemented daily suggesting the steers were able to efficiently utilize large boluses of nutrients fed every other day. The effect of less frequent supplementation on IGF-1 deserves further examination as this hormone has been shown to increase protein synthesis.

Key words: cattle, insulin, insulin-like growth factor 1, metabolism, supplementation frequency


INTRODUCTION

Supplements are often fed to growing cattle to improve animal performance with the ultimate goal of increasing economic return. When supplementation frequency is reduced, the amount of supplement fed each week remains the same but the amount fed during each supplementation event is increased. This can exacerbate any negative effects of supplementation on forage intake and digestion (Kunkle et al., 2000). A supplement containing a mixture of soybean hulls and corn gluten feed has many favorable characteristics (high in digestible fiber, low in nonstructural carbohydrates, and high in ruminally degradable protein) that allows it to be fed less frequently to cattle consuming forage without negatively affecting digestion (Drewnoski and Poore, 2012). Compared to daily supplementation, less frequent supplementation (2 or 3 times a week) with a soybean hull and corn gluten feed mix did not appear to affect gains of steers consuming medium quality grass hay but did consistently reduce hay intake (Drewnoski et al., 2011). Therefore, steers fed less frequently with a soybean hull and corn gluten feed blend may have a greater gain to feed ratio (more efficient) than those supplemented daily. Reduction of supplementation

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frequency changes the pattern of incoming nutrients and could therefore alter blood concentrations of hormones. Increased rates of gain in cattle have been associated with increased concentrations of insulin and IGF-1 (Bishop et al., 1989; Vizcarra et al., 1998; Lapierre et al., 2000). Therefore, increases in insulin or IGF-1 could explain the greater efficiency of steers supplemented less frequently that has been observed in some studies. The objectives of this study were to compare the effect of daily vs. alternate day supplementation of a soybean hull and corn gluten feed mix on growth and hay intake of individually fed steers and to determine the effect of supplementation frequency on concentrations of metabolites and hormonal growth regulators in blood.

MATERIALS AND METHODS

The protocol for this study was approved by the Institutional Animal Care and Use Committee at North Carolina State University. Eighteen Angus or Angus × Simmental cross steers (287 ± 20 kg and 310 ± 3.6 d) were blocked by weight and breed and randomly assigned to 1 of 3 treatments. Before the beginning of the trial steers were dewormed (Cydectin; Fort Dodge Animal Heath, Overland Park, KS). Dietary treatments consisted of ad libitum hay and no supplement (NS), ad libitum hay and 1% BW (as-fed basis) of supplement daily (DS), or ad libitum hay and 2% BW (as-fed basis) of supplement every other day (SA). Steers began being fed their dietary treatment on d 1 of the trial and continued to be fed their treatment throughout the remainder of the trial. The supplement contained (as-fed basis) 47% corn gluten feed, 47% soybean hulls, 2% feed grade limestone, and 4% molasses. Steers were fed supplement at 0800 h and hay was provided 30 min later. Steers not receiving supplement were fed hay at 0800 h. Hay was offered in 2 portions (one-half in morning and one-half in afternoon at 1530 h). Hay was offered at 110% of the previous day’s intake for NS and DS steers. The hay offered to the SA steers on days they received supplement was 110% of the previous day they received supplement and hay offered on days they did not receive supplement was 110% of the intake from the previous day they did not receive supplement. Steers had access to a trace mineral block (Buckeye Feed Mills, Inc., Dalton, OH; 96 to 98% NaCl, 0.5% Zn, 0.4% Mn, 0.25% Cu, and 0.004% Se) throughout the trial.

Hay and supplement was sampled weekly for determination of nutrient content throughout the trial. Before feeding, the square baled tall fescue hay (Lolium arundinaceum (Schreb.) Darbysh.) was sliced using a S600 VanDale Bale Processor 197 (J-Star Industries, Fort Atkinson, WI) with the blades spaced 12.5 cm apart. Due to a limited supply of a single lot of hay, 3 different hay lots were fed. During the first 20 d of the trial all steers received endophyte-infected Kentucky-31 fescue hay. On d 21, 3 blocks of steers (1 heavy, 1 medium, and 1 light weight block) began receiving novel endophyte-infected HiMag fescue hay (Ark+) and 3 blocks of steers (1 heavy, 1 medium, and 1 light weight block) began receiving novel endophyte-infected Jessup fescue hay (MaxQ).

The 2 novel endophyte-infected hays were cut from adjacent fields at the same time and thus were similar in nutrient content (Table 1). Feed was dried in a forced-air oven at 55°C to a constant weight and then air-equilibrated for 48 h to determine air-equilibrated DM. Samples were then ground in a Model 4 Wiley mill (Arthur A. Thomas Co., Philadelphia, PA) to pass through a 1-mm screen. Dry matter (105°C), ash, and Kjeldahl N were determined according to AOAC (1999) procedures. Concentrations of NDF and ADF were sequentially determined as described by Van Soest et al. (1991) but modified for use with an Ankom apparatus (Ankom Technology, Macedon, NY). The DM, CP, NDF, and ADF content of the hay and supplement is shown in Table 1. The supplement was analyzed for mineral content by a commercial laboratory (Cumberland Valley Analytical Services, Maugansville, MD) according to the AOAC (2000) method 985.01 and contained 0.76% Ca, 0.68% P, and 0.30% S on a DM basis.

### Performance and Intake

Steers were housed in groups of 6 in a 13 m² pen with slotted floors and an automatic waterer. Steers were individually fed using Calan gate electronic feeders (American Calan, Northwood, NH). Before the beginning of the trial weights were taken before the morning feeding on 2 consecutive days (d –2 and –1) followed by a 16-h shrunken weight (d 0). Steers were weighed before the morning feeding on d 25 and 26 and the amount of supplement fed was adjusted based on these weights. Two consecutive weights were taken in the morning before feeding on d 52 and 53. In the afternoon on d 53, feed and water was removed and weights were taken the

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<tr>
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<tr>
<td>Supplement</td>
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<td>17.2</td>
<td>48.0</td>
<td>26.6</td>
<td>70</td>
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2The supplement was formulated (as-fed basis) to contain 47% soybean hulls, 47% corn gluten feed, 2% feed grade limestone and 4% molasses.

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following morning (shrunken weights). Hay intake from d 1 and 2 was not included in the analysis because intake was abnormally high due to steers being previously fasted for determination of shrunken weights.

**Serial Blood Sampling**

From d 63 to 80, serial blood samples for hormone and metabolites were measured. Before the start of the serial blood sampling phase, the amount of supplement being fed was adjusted based on full weights taken on d 52 and 53. On d 54, the heaviest 2 blocks of steers (1 being fed MaxQ and the other Ark+) were placed in individual metal tie stalls (1.5 by 3 m) with a feeder and watering. Steers were adapted to tie stalls for 8 d and on d 62 these steers were fitted with indwelling jugular catheters to measure circulating hormone and metabolite levels. On d 63, intensive blood samples were collected every hour from 0600 to 1400 h and additional blood samples were taken at 1800, 2200, and 0200 h on both days.

Blood samples were collected into 10 mL Vacutainer tubes (Becton Dickinson Vacutainer Systems, Franklin Lakes, NJ) with heparin as the anticoagulant. During the blood sampling procedure 5 mL of blood and anticoagulant was drawn and discarded and then a 10 mL blood sample was saved and 4 mL of heparin was used to flush the catheter. Blood samples were placed on ice until plasma was harvested and frozen at –20°C. On d 59, the 2 medium weight blocks of steers began adaptation in wooden tie stalls (1.2 by 3 m) and were moved to metal tie stalls on d 65 d. On d 70, they were catheterized followed by blood sampling on d 71 and 72. The lightest 2 blocks of steers began adaptation in the wooden stalls on d 67, were moved to tie stalls on d 73, and were catheterized on d 77, and blood samples were taken on d 78 and 79.

**Blood Analysis**

Insulin and glucose, were measured on all samples taken during the 2-d period. Plasma insulin was measured using a commercial solid-phase radioimmunoassay (Coat-A-Count insulin kits; Diagnostic Products Corporation, Los Angeles, CA) using bovine insulin as a standard. Plasma was analyzed for glucose according to Brann and Luebbe’s colorimetric method G-142-95, revision 1 (Bran and Luebbe Auto Analyzer Methods). Plasma urea-N (PUN) was analyzed by the diacetyl monoxime method of Marsh et al. (1965 on samples taken every 4 h over the 2-d period (0600, 1000, 1400, 1800, 2200, and 0200 h), using a Technicon Auto Analyzer (Technicon Instruments Corporation, Tarrytown, NY). For determination of IGF-1 concentration, 200 μL of plasma from samples taken every 4 h were pooled within day and quantified by radioimmunoassay using a commercial kit (DSL-2800; Linco Research, St. Charles, MO).

**Statistical Analysis**

All data were analyzed using the Mixed procedure of SAS (SAS Inst. Inc., Cary, NC) and the effects of block, breed, and steer (treatment × hay) were considered random. The model for insulin, glucose, and PUN concentrations included the fixed effect of treatment, hay type, day, time, and their interactions. The model used time within day as the repeated measure. Variance components (VC) was selected as the covariance structure for the repeated model based on this model having the lowest Akaike’s information corrected criterion (AICC). Analysis of hay intake and IGF-1 concentration included the effects of treatment, day, hay type, and their interaction. The analysis of ADG and area under the concentration time curve for insulin, glucose, and PUN included the effects of treatment, hay type, and their interaction. Nonsignificant (P > 0.20) interactions were removed from the model. Data reported are least square means. When the F-test was significant (P ≤ 0.05), the PDIFF statement was used to separate LSMEAN. Significance was declared at P ≤ 0.05 and tendencies were declared from P = 0.06 to 0.10.

**RESULTS**

**Hay Intake and Average Daily Gain**

There was a treatment × hay type × day interaction for hay intake (P < 0.01; Fig. 1). For all hay types the hay intake of NS was greater (P < 0.01) than DS, and the hay intake of SA on the day they received supplement was lower (P < 0.01) than both NS and DS. For all hay types, hay intake of SA increased on the day they did not receive supplement, but the extent of the increase varied among hay types. When steers were fed Kentucky-31 during the first part of the trial, hay intake of SA on unsupplemented days was intermediate between NS and DS. During the second half of the trial, hay intake of SA on unsupplemented days was greater (P < 0.01) than DS and did not differ (P = 0.54) from NS when steers were fed Ark+. However, when steers were fed MaxQ, hay intake of SA on the day they did not receive supplement was lower (P < 0.01) than NS and only tended to be greater (P = 0.07) than DS. For all hay types, the mean hay intake of DS and SA did not differ (P ≥ 0.66) but were lower (P < 0.01) than NS. The mean hay intake across all hay types for each treatment is shown in Table 2.

There was a treatment × hay × day interaction (P < 0.01) and treatment × day interaction (P < 0.01) for both ME and CP intake. Figure 2 shows the ME and CP intake of the treatments across all hay types on each day.
Supplementation frequency and plasma profiles

The ME and CP intake of SA on the day that they received supplement was increased \( (P < 0.01) \) by supplementation frequency (Table 2). There was a tendency for hay type \( (P < 0.01) \) than DS and NS on the day before and after the day (SA) at 2% of BW (as-fed basis) with a soybean hulls and corn gluten feed blend (90% DM). Bars without common letters differ \( (P < 0.05) \).

Blood Metabolites and Hormones

Insulin concentrations (Fig. 3B) of NS remained steady with a mean concentration of 11.5 μIU/mL over the 48-h period. Insulin concentration of DS also remained relatively steady over the 48-h period. Insulin concentration of DS was greater \( (P < 0.05) \) than NS, except during the 2-h period immediately before supplementation during which time insulin decreased and did not differ \( (P > 0.20) \) from NS. Insulin concentrations of SA had a greater range in concentration over the 48 h period. Insulin concentration of SA before supplementation (0200 h on d 1) did not differ \( (P > 0.20) \) from NS but increased following supplementation and remained greater \( (P < 0.05) \) than NS until 2200 h on d 2 (a 34-h period). By 2 h after supplementation (d 1) insulin concentration of SA was greater \( (P \leq 0.05) \) than DS and remained greater \( (P < 0.05) \) than DS throughout the 22-h period after supplementation. On d 2, insulin concentrations of SA began to decrease and by 2200 h insulin concentrations of SA were lower \( (P < 0.01) \) than DS and remained lower \( (P < 0.05) \) until the next supplementation event.

Plasma IGF-1 did not differ due to day \( (P = 0.72) \) but was affected by treatment \( (P < 0.01; \) Fig. 4). Plasma IGF-1 was increased \( (P < 0.01) \) due to supplementation and was greater \( (P = 0.04) \) for SA compared with DS.

There was a treatment \( \times \) day \( \times \) time interaction \( (P < 0.01) \) for PUN. Peak concentrations of both DS (13.2 mg/dL) and SA (13.4 mg/dL) were greater \( (P < 0.01) \) than NS (11.50 mg/dL). Despite the intake of a larger bolus mately 2 h) of decreased glucose concentration was also observed for NS around the morning hay feeding. However, the glucose concentration of SA on the day supplementation was not fed (d 2) did not decrease due to the morning hay feeding. This caused the glucose concentration of SA on the day they did not receive supplement (d 2) to be greater \( (P < 0.02) \) than DS for a 3-h period around supplementation on d 2. Glucose concentrations of DS and SA did not differ \( (P > 0.10) \) at any other time points during the 48-h period.

Table 2. Average daily gain, mean hay intake (DM basis), and gain to feed ratio (DM basis) of steers fed ad libitum medium quality tall fescue hay and either not supplemented (NS), supplemented daily (DS) at 1% of BW (as-fed basis), or supplemented every other day (SA) at 2% of BW (as-fed basis) with a soybean hulls and corn gluten feed blend (90% DM)

<table>
<thead>
<tr>
<th>Item</th>
<th>NS</th>
<th>DS</th>
<th>SA</th>
<th>SEM</th>
<th>P-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>ADG(^1), kg/d</td>
<td>0.45(^b)</td>
<td>0.90(^a)</td>
<td>0.87(^a)</td>
<td>0.05</td>
<td>&lt;0.01</td>
</tr>
<tr>
<td>Hay DMI, kg/d</td>
<td>6.1(^a)</td>
<td>4.5(^b)</td>
<td>4.3(^b)</td>
<td>0.33</td>
<td>&lt;0.01</td>
</tr>
<tr>
<td>Gain to feed ratio</td>
<td>0.070(^b)</td>
<td>0.123(^a)</td>
<td>0.122(^a)</td>
<td>0.008</td>
<td>&lt;0.01</td>
</tr>
</tbody>
</table>

\(^{ab}\) Means on the same row not sharing a common superscript differ \( (P \leq 0.05) \).
\(^1\) ADG based on weights taken on d 0 and 53 after 16 h shrink (feed and water removal).

Figure 1. Hay DMI of steers given ad libitum access to medium quality Kentucky-31 (Ky-31) endophyte-infected tall fescue hay from d 3 to 20 and novel endophyte-infected HiMag fescue hay (Ark+) or novel endophyte-infected Jessup fescue hay (MaxQ) from d 21 to 52 and either not supplemented (NS), supplemented daily (DS) at 1% of BW (as-fed basis), or supplemented every other day (SA) at 2% of BW (as-fed basis) with a soybean hulls and corn gluten feed blend (90% DM).
of N on the day SA was supplemented (d 1), the peak PUN concentration of SA did not differ \((P = 0.82)\) from DS (Fig. 5). The PUN nadir of SA (6.19 mg/dL) did not differ \((P = 0.25)\) from DS (7.12 mg/dL) but was lower \((P < 0.01)\) than NS (8.15 mg/dL). Although DS and SA had more fluctuation in PUN concentrations than NS, the mean PUN concentration (9.7 mg/dL) did not differ due to treatment \((P = 0.77)\).

The area under the glucose, insulin, and plasma urea-N concentration-time curves are shown in Table 3. The area under the glucose concentration-time curve on each day of the 2-d supplementation cycle and across the 2-d supplementation cycle was increased \((P < 0.01)\) by supplementation but did not differ \((P \geq 0.53)\) due to supplementation frequency. The area under the insulin concentration-time curve was greater \((P \leq 0.02)\) for DS than NS on both days of the supplementation cycle. On the day that SA received supplement the area under the insulin concentration-time curve was greater \((P \leq 0.02)\) for SA than both DS and NS. However, on the day that SA did not receive supplement, the area under the insulin concentration-time curve of SA did not differ from NS \((P = 0.14)\) and was lesser \((P = 0.02)\) than DS. Across the 2-d supplementation cycle, the area under the insulin concentration-time curve was increased \((P < 0.01)\) by supplementation but did not differ \((P = 0.67)\) due to supplementation frequency. The area under the PUN concentration-time curves on both days and across 2-d supplementation cycle did not differ \((P \geq 0.65)\) due to treatment.

**DISCUSSION**

Often growing cattle consuming hay-based diets are given high energy supplements containing moderate amounts of protein to increase performance. However, supplements often decrease forage intake when forage TDN:CP ratio is less than 7, supplemental TDN is greater than 0.7% BW, or forage intake when fed alone is greater than 1.75% of BW (Moore et al., 1999). All of which occurred in this study and thus the fact that hay intake was reduced by supplementation was not unexpected. However, less information is available on the conditions that may affect forage substitution rate when less frequent supplementation is used. We have previously observed that less frequent supplementation (2 or 3 times a week) at a rate equivalent to 1% BW/d of growing steers with a soybean hull and corn gluten feed blend (90% DM) reduced overall hay intake compared to those supplemented daily but did not affect gain (Drewnoski et al., 2011). In agreement with our previous study, gains in the current study did not differ due to supplementation frequency. However, in the current study a further reduction in hay intake was not observed when cattle were supplemented on...
Supplementation frequency and plasma profiles

Alternate days compared to daily supplementation. For steers supplemented 3 times a week (3X), hay intake on the day following supplementation was equal to those that were supplemented daily (Drewnoski et al., 2011). In the current study, the hay intake of SA steers on the day they did not receive supplement was usually greater than those supplemented daily thus causing hay intake over the 2-d supplementation cycle to be similar for SA and DS. However, there was an interaction between hay source and treatment caused by a difference in response of SA on the day they were not supplemented. When steers were fed Kentucky-31, the hay intake of SA on the day they were not supplemented was greater than DS but less than NS. Despite the fact that CP and ADF content were almost identical between the MaxQ and Ark+, hay intake of SA steers fed MaxQ remained depressed on the day that SA was not supplemented and did not differ from DS whereas hay intake of SA steers fed Ark+ increased to equal that of NS on the day they were not supplemented. Due to the relative short feeding period of each hay source no interactions of hay source and treatment were detected for ADG. More research on the effect of hay source on response to less frequent supplementation may be warranted.

Alternate day supplementation of a blend of soybean hulls and corn gluten feed at a rate equivalent to 1% BW/d can be implemented without negatively affecting digestibility (Drewnoski and Poore, 2012). A blend of soybean hulls and corn gluten feed is high in energy but low in nonstructural carbohydrates (NRC, 1996). It also contains a moderate amount of protein (17%; Table 1), much (77%) of which is ruminally degradable (NRC, 1996). Success of less frequent supplementation of energy based supplements may at least partially depend on availability of ruminal N for efficient microbial growth and digestion. Loy et al. (2008) showed that the effects of supplementation frequency on gains of heifers consuming medium quality hay tended to differ depending on the source of protein used in the energy supplement. Hay intake was decreased but gains were not negatively affected by reducing supplementation frequency to 3 times a week when a supplement high in ruminally degradable protein (dry rolled corn plus urea) was fed. Thus, the heifers supplemented with dry rolled corn and urea 3X had a greater gain to feed ratio than those supplemented daily in their study. Additionally, the purine derivative to creatinine ratio in the urine was greater for heifers supplemented with dry rolled corn plus urea 3X than those supplemented daily suggesting that heifers supplemented 3X absorbed more microbial protein (Loy et al., 2008).

We have previously observed that SA had a greater peak in rumen ammonia-N following supplementation that those supplemented daily (14 vs. 8 mg/dL) and also had a lower ruminal pH (5.8 vs. 6.1) than DS following supplementation (Drewnoski and Poore, 2012). In the present study, the peak concentration of PUN following supplementation did not differ between DS and those SA despite SA consuming twice as much supplement at once. The lower pH in the rumen of SA may have decreased the rate absorption of ammonia into the blood stream as the ionized molecule (NH$_4^+$) is less permeable than its unionized (NH$_3$) counterpart (Smith, 1979). It is possible that reduced rate of absorption may have prolonged the supply of ruminal-N and allowed for increased microbial growth.

Compared to DS the insulin concentration of SA was greater for 24 h, equal for 14 h, and lower for 10 h during the 48-h period. The increase in insulin concentration may have been due to increased absorption of volatile fatty acids in to the portal blood or changes in the profile of volatile fatty acids that were absorbed. In ruminants, insulin increases in response to increased absorption of

**Figure 4.** Plasma IGF-1 concentration of steers fed ad libitum medium quality tall fescue hay and either not supplemented (NS), supplemented daily (DS) at 1% of BW (as-fed basis), or supplemented every other day (SA) at 2% of BW (as-fed basis) with a soybean hulls and corn gluten feed blend (90% DM). Treatment effect ($P < 0.01$).

**Figure 5.** Plasma urea-N (SEM ± 0.54) concentration of steers fed ad libitum medium quality tall fescue hay and either not supplemented (NS), supplemented daily (DS) at 1% of BW (as-fed basis), or supplemented every other day (SA) at 2% of BW (as-fed basis) with a soybean hulls and corn gluten feed blend (90% DM). Steers being SA only received supplement on d 1.
propionate and butyrate (Manns and Boda, 1967). We have previously observed that on the day of supplementation molar proportions of both propionate and butyrate in the rumen of SA were increased compared to DS (Drewnoski and Poore, 2012). The major role of insulin is the promotion of metabolites in storage in peripheral tissues. Insulin is the major regulator of glucose metabolism and is also known to regulate protein metabolism. Insulin induces protein accretion by stimulating protein synthesis and inhibiting proteolysis (Lobley, 1998). Increased concentrations of insulin have been shown to decrease the utilization of amino acids for glucose production in ruminants and increase the incorporation of amino acids into muscle protein (Tesseraud, 2007). Increased concentrations of insulin can decrease the utilization of glucogenic amino acids for glucose production (Huntington et al., 2006). Therefore, increased insulin of SA may have spared some glucogenic amino acids and allowed them to be utilized for growth.

Insulin-like growth factor 1 is an endocrine regulator of muscle growth in cattle and forms a vital link between growth hormone and the metabolic process of growth. Like insulin, IGF-1 has been shown to increase protein synthesis in skeletal muscle and reduce the rate of protein degradation (Florini et al., 1996). The IGF-1 concentration of SA was greater than DS and did not vary due to day (supplemented vs. not supplemented). Concentrations of IGF-1 are responsive to both plane of nutrition as well as the composition of the diet with level of protein appearing to be more important that energy content (Pell and Bates, 1990). However, Elsasser et al. (1989) showed that a certain level of energy intake is needed for IGF-1 concentrations in cattle to respond to level of protein intake. Cattle consuming 12.4 Mcal ME/d were less able to respond to increased CP (0.5 to 0.9 kg/d) than cattle consuming 17.0 Mcal ME/d. The ME and CP intake of SA on the day these steers received supplement was considerably high (24.0 Mcal ME and 1.3 kg CP) but on the day these steers did not receive supplement, ME intake was only 12.5 Mcal and CP intake was 0.52 kg. However, mean ME and CP intake over the 48-h period of SA and DS did not differ. More work is needed to understand why SA steers had greater IGF-1 than DS steers despite both treatments essentially consuming the same amount of nutrients over a 48-h period. Increased availability of amino acids for anabolism may be responsible for greater concentration of IGF-1 observed in SA. Steers on SA may have had increased absorption of microbial protein as was observed by Loy et al. (2008) or decreased utilization of amino acids for gluconeogenesis due to increased concentrations of propionate and insulin on the day of supplementation.

Little research has examined the effects of supplementation frequency on metabolic regulators. Studies from the University of Florida have examined the effects of supplementation frequency when growing cattle consuming low quality forage were supplemented with a citrus pulp/cottonseed meal supplement (Cooke et al., 2007) or a wheat middling-based supplement (Cooke et al., 2008) daily (1% BW) or 3X (2.3% BW). Unlike the present study, gains of supplemented cattle were low (<0.45 kg ·hd⁻¹·d⁻¹) and were reduced by less frequent supplementation in both studies. Insulin-like growth factor 1 was not increased by less frequent supplementation. However, no unsupplemented control was used to determine if supplementation had an effect on IGF-1. In both studies, the nutrient content of the forage alone would probably have been below maintenance. The nutrient intake of SA in our studies would have been above maintenance even on unsupplemented days. Therefore, given the fact that a certain level of energy intake must be achieved for IGF-1 to be increased by increasing CP intake, plane of nutrition may explain the difference observed between our studies and those of Cooke et al. (2007, 2008). Plane of nutrition may be an important factor in determining the metabolic response of growing cattle to less frequent supplementation. Success of less frequent supplementation may depend on the quality of forage being supplemented as well as the characteristics of the supplement. It appears that when digestion was not negatively affected and forage quality is above maintenance steers supplemented on al-
ternate days were able to as efficiently utilize the nutrients when supplemented less frequently despite a larger fluctuation in the pattern of incoming nutrients. However, other differences between the University of Florida studies and the present study may also play a role in the difference in response to less frequent supplementation observed, including gender and breed of the cattle used. The University of Florida studies used Brahman-cross (*Bos indicus*) heifers whereas our current and past studies (Drewnoski et al., 2011) used Angus-cross (*Bos taurus*) steers.

Gains of steers supplemented with a soybean hull and corn gluten feed blend on alternate days did not differ from those supplemented daily, suggesting the steers were able to efficiently utilize large boluses of nutrients fed every other day. The IGF-1 concentration of steers supplemented with a soybean hull and corn gluten feed blend on alternate days was greater than steers supplemented daily and did not vary due to day (supplemented vs. not supplemented). The effect of less frequent supplementation on IGF-1 deserves further examination.

**LITERATURE CITED**


