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Effects of frequency of concentrate supplementation on performance of early-weaned beef calves consuming annual ryegrass

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ABSTRACT

Objective: The objectives of this study were to evaluate the growth performance during a grazing period (experiment 1) and forage intake and apparent in vivo digestibility (experiment 2) of early-weaned beef calves consuming annual ryegrass (*Lolium multiflorum*) and supplemented with concentrate either daily or 3 times weekly.

Materials and Methods: The experiment was conducted in Ona, Florida. Treatments consisted of similar weekly concentrate amounts (1% of BW × 7 d) divided into equal amounts and then offered daily (7×) or 3 times weekly (3×) to early-weaned beef calves consuming annual ryegrass pastures from d 0 to 84 (experiment 1) and annual ryegrass hay in drylot from d 84 to 105 (experiment 2).

Results and Discussion: From d 0 to 84, reducing the frequency of concentrate supplementation did not influence herbage mass, herbage allowance, or nutritive value of annual ryegrass pastures, or calf ADG, BW, or plasma concentrations of glucose and urea N. The overall forage DM intake was 15% less for 3× versus 7× calves (1.51 vs. 1.78% of BW, respectively). Total DM intake did not differ between 3× and 7× (2.63 vs. 2.73% of BW, respectively), whereas in vivo apparent digestibility decreased for 3× versus 7× (85.3 vs. 86.5%, respectively).

Implications and Applications: Reducing frequency of concentrate supplementation from daily to 3 times weekly did not affect overall growth performance of early-weaned beef calves consuming annual ryegrass and can successfully be implemented to reduce feeding costs.

Key words: beef calves, early weaning, supplementation frequency, annual ryegrass

INTRODUCTION

Reducing the frequency of concentrate supplementation can be implemented to decrease feeding costs while maintaining the weekly supplement amount (Drewnoski et al., 2011). However, this strategy affects forage digestion, resulting in fluctuations in forage and nutrient intake and hormones and metabolites associated with energy and protein metabolism (Moriel et al., 2012) and, consequently, variable outcomes in growth, reproduction, and immune function among cattle. For instance, concentrate supplementation offered at 3 versus 7 times weekly decreased or did not affect the growth and reproduction of replacement beef heifers (Cooke et al., 2008; Moriel et al., 2012, 2020), growing beef steers (Drewnoski et al., 2011), and beef cows and their offspring (Moriel et al., 2016a; Izquierdo et al., 2022). In recently weaned beef calves undergoing a physiological stress, reducing the frequency of concentrate supplementation exacerbated the post-vaccination inflammatory response (Silva et al., 2018) and decreased growth and antibody production against respiratory pathogens (Artioli et al., 2015; Moriel et al., 2016b).

Early-weaned beef calves are separated from their dam at approximately 60 to 90 d of age to increase cow reproductive performance in the upcoming breeding season (Arthington and Kalmbacher, 2003). Early-weaned beef calves have a relatively small rumen capacity, limiting forage DM intake (Paisley et al., 1998). Therefore, these calves rely on grain- or byproduct-based concentrate to achieve greater total nutrient intake and growth performance (Vendramini and Moriel, 2018). The effects of reducing the frequency of concentrate supplementation on growth, forage DM intake, and digestibility of early-weaned beef calves consuming cool-season grasses remains unknown. We hypothesized that reducing the frequency of concentrate supplementation from daily to 3 times weekly would not influence growth performance and average weekly forage DM intake of early-weaned beef calves consuming annual ryegrass. Our objectives were to evaluate the growth performance during a grazing period (ex-

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periment 1) and forage DM intake and apparent in vivo digestibility (experiment 2) of early-weaned beef calves consuming ryegrass and supplemented with concentrate either daily or 3 times weekly.

MATERIALS AND METHODS

Experiments 1 and 2 were conducted at the University of Florida, Institute of Food and Agricultural Sciences, Range Cattle Research and Education Center, Ona, Florida (27° 26′ N and 82° 55′ W) from February to April of 2019 and 2020 (experiment 1) and April to May of 2019 and 2020 (experiment 2). All calves were cared following the protocol (no. 201910564) approved by the Institutional Animal Care and Use Committee of the University of Florida.

Experiment 1 (Grazing Period; D 0 to 84)

Twelve days before the start of experiment 1, 64 Brangus crossbred calves (16 steers and 16 heifers per year; 2 yr) were weaned at 90 ± 15 d of age and 89 ± 7 kg of BW. Calves remained in a single drylot pen with free-choice access to long-stem stargrass hay (*Cynodon nlemfuensis*) and supplemented with 1 kg/d of concentrate (guaranteed analysis, as fed: 14% CP, 1.0% fat, 18% fiber, 0.75% Ca, 0.40% P, and 0.40% NaCl; Land O'Lakes Purina Feed LLC) for 12 d. On d 0, calves were stratified by sex, initial BW, and age, and then were randomly allocated into 1 of 8 pastures (0.30 ha per pasture; 2 steers and 2 heifers per pasture per year) of annual ryegrass. Treatments were randomly assigned to pastures on d 0 (4 pastures per treatment per year) and consisted of calves offered the same weekly concentrate DM amount (1% BW × 7 d), divided into equals amounts and offered either daily (**7×**) or 3 times weekly (**3×**; Mondays, Wednesdays, and Fridays) at 0800 h from d 0 to 84. The weekly concentrate DM amount was selected based on a previous study comparing incremental amounts of concentrate DM (0, 1, and 2% of BW) for early-weaned beef calves grazing annual rye–ryegrass mixtures (Vendramini et al., 2006) and was adjusted every 28 d from d 0 to 84. Concentrate composition was designed for early-weaned beef calves (Oliveira et al., 2020) and consisted of (DM basis) 21.0% soybean (*Glycine max*) hulls, 15.7% cottonseed (*Gossypium hirsutum*) meal, 15.0% cottonseed hulls, 8.8% wheat middlings (*Triticum aestivum*), 8.0% dried distillers grains, 8.0% citrus pulp pellets (*Citrus* spp.), 7.8% cracked corn (*Zea mays*), 7.8% corn meal, 5.4% soybean meal, 2.0% sugarcane molasses (*Saccharum officinarum*), 0.50% calcium carbonate, 0.05% trace mineral premix, and 0.02% vitamin E (DM basis: 78% TDN and 16% CP). From d 0 to 84, all calves were provided free-choice access to water and a salt-based trace mineral supplement (University of Florida Cattle Research Winter Mineral, Vigortone AG Products; 16.8%, 1.0%, 20.7%, and 4.0% of Ca, Mg, NaCl, and P; and 60, 1,750, 350, 60, and 5,000 mg/kg of Co, Cu, I, Se, and Zn).

"Jumbo" annual ryegrass was seeded in a prepared seedbed using a drill (Pasture Pleaser, Agco-Tye) on November 15, 2018, and November 19, 2019, using a seeding rate of 22.4 kg/ha. Annual ryegrass was fertilized with 56, 14, and 56 kg/ha of N, P_2O_5, and K_2O, respectively, approximately 2 wk after seeding. In addition, pastures were fertilized with 60 kg of N/ha in early February 2019 and 2020. The source of the N fertilizer was ammonium nitrate.

Experiment 2 (Drylot Period; D 84 to 105)

On d 84, a subsample of calves (6 steers and 6 heifers per treatment in year 1; 5 steers and 5 heifers per treatment in year 2) were randomly selected and assigned to 1 of 24 individual concrete floor pens (18 m^2 per pen) in a fully covered drylot facility to evaluate their daily forage and total DM intake (concentrate + hay) and total apparent DM digestibility for 21 d (d 84 to 105). During this period, calves continued receiving their previous respective frequency of concentrate supplementation (7× or 3×) and were provided daily free-choice access to ground annual ryegrass hay (DM basis: 22% CP, 30% ADF, 70% NDF, 60% TDN). The evaluation period consisted of adaptation from d 84 to 94, daily forage intake data collection from d 95 to 105, and daily fecal sample collection at 0800 and 1600 h from d 103 to 105.

The annual ryegrass for hay production was established on November 15, 2018, with the same management practices used for the annual ryegrass pastures described in experiment 1. The hay was harvested on March 25, 2019, and was used for experiment 2 in 2019 and 2020.

Sample and Data Collection

Experiment 1. Each pasture was sampled on d 0, 28, 56, and 84 of years 1 and 2 to determine the herbage mass, herbage allowance, and forage concentrations of CP and in vitro digestible OM (**IVDOM**). Herbage mas was determined using the double sampling technique (Gonzalez et al., 1990), as described by Oliveira et al. (2020). Herbage allowance was calculated as the average herbage mass divided by the average total BW of calves in each respective pasture (Sollenberger et al., 2005). Forage samples were dried at 55°C for 72 h in a forced-air oven, and then ground to pass a 1-mm screen (Model 4, Thomas-Wiley Laboratory Mill, Thomas Scientific) before analyzes of CP and IVDOM. Forage IVDOM was determined as described by Moore and Mott (1974), whereas forage N concentration was determined using the modified micro-Kjeldahl, aluminum block digestion technique (Gallaher et al., 1975). Final forage CP concentration was achieved by multiplying the respective forage N concentration by 6.25. Concentrate samples were collected every 28 d, pooled across days, and then sent to Dairy One Forage Laboratory (Ithaca, NY) to determine the wet chemistry analysis of CP and TDN.

Individual calf shrunk BW was recorded at 0800 h (before concentrate feeding) on d 0, 28, 56, and 84, following

12 h of food and water withdrawal. Approximately 10 mL of blood samples were collected from all calves via jugular venipuncture into tubes containing sodium heparin (Vacutainer, Becton Dickinson) on d 0, 28, 56, and 84. All blood samples were centrifuged at 2,000 × g at 4°C for 30 min, and plasma was harvested and kept frozen at −80°C until laboratory analysis. Plasma samples were used to assess the concentrations of glucose and urea nitrogen using quantitative colorimetric kits (nos. G7521 and B7551, respectively; Pointe Scientific Inc.). Intra- and interassay coefficients of variation were 3.0 and 4.3% for glucose and 2.7 and 3.9% for plasma urea N, respectively.

Experiment 2. Individual calf shrunk BW was recorded at 0800 h (before concentrate feeding) on d 84 and 105, following 12 h of food and water withdrawal. Samples of ryegrass hay and concentrate samples were collected daily, dried at 55°C for 72 h in a forced-air oven, and then ground to pass a 1-mm screen to assess the DM concentration of both hay and concentrate, which were used to calculate the daily forage and total (concentrate + hay) DM intake from d 84 to 105. Rectal fecal samples were collected individually at 0800 and 1500 h on d 103, 104, and 105, and then pooled across d 103 to 105 to determine in vivo total apparent DM digestibility using the indigestible NDF procedure. Concentrations of indigestible NDF in forage, concentrate, and feces were determined as described by Cole et al. (2011) using modifications proposed by Krizsan and Huhtanen (2013). Dried samples of forage, concentrate, and feces were analyzed for NDF concentration using the method described by Van Soest et al. (1991) but adapted for an Ankom 200 Fiber Analyzer (Ankom Technology Corp.). Total feces output and apparent DM digestibility were calculated according to Vendramini et al. (2018).

Statistical Analyses

All data collected herein were analyzed as a complete randomized study using pasture as the experimental unit and MIXED procedure of SAS (version 9.4, SAS Institute Inc.). Effects of year, supplementation frequency × year, pasture(supplementation frequency) and calf(pasture) were included in the model as random effects in all statistical analyses. Pasture(supplementation frequency), year, and supplementation frequency × year were the random effects included in the model in the statistical analyses of all forage data. Calf BW and ADG, calf plasma data, and all forage data (experiment 1) were analyzed as repeated measures and evaluated for fixed effects of supplement frequency, day of study, and resulting interaction. Calf(pasture) and pasture were included as subjects in the repeated measures analyses of calf performance and forage data, respectively. The compound symmetry covariance structure was selected for all analyses of repeated measures because it generated the lowest Akaike information criterion. In vitro apparent digestibility and BW change (experiment 2) were tested for fixed effects of supplement frequency. Effects of calf sex and calf BW, plasma data, and forage data collected on d 0 were included as covariates in the model for all calf performance variables but removed from the model when $P \geq 0.10$. Results were reported as least squares means, and means were separated using PDIFF when a significant F-test was detected. Significance was set at $P \leq 0.05$ and tendencies when $P >$ 0.05 and ≤0.10.

RESULTS AND DISCUSSION

Effects of day of the study, but not supplementation frequency × day of the study or supplementation frequency ($P \geq 0.23$), were detected ($P \leq 0.007$) for herbage mass, herbage allowance, CP, and IVDOM in experiment 1 (Table 1). The reduction in herbage mass was associated with the advancing plant maturity reducing annual ryegrass herbage accumulation (Vendramini and Arthington, 2008) in addition to the greater forage DM intake of calves from d 0 to 84. Nonetheless, herbage allowance from d 0 to 84 was always above the minimum threshold required to achieve ad libitum ryegrass DM intake for early-weaned beef calves (0.5 kg of DM/kg of BW; Vendramini et al., 2006). Annual ryegrass CP increased from d 28 to 56 (P = 0.002) and did not differ between d 28 and 56 (P = 0.61; Table 1), whereas IVDOM gradually decreased (P ≤ 0.003) from d 28 to 84 (Table 1). Changes to annual ryegrass nutritive value reflected the advancing plant maturity and the appearance of reproductive stems, leading to increased stem:leaf ratio, decreased soluble compounds, and increased cell wall components (Vendramini and Arthington, 2008). Despite the changes to the nutritive value of ryegrass, CP and IVDOM were above the protein and energy requirements of early-weaned beef calves (NASEM, 2016). Therefore, herbage mass and nutritive value of annual ryegrass pastures were not limiting factors for calf performance from d 0 to 84.

Effects of day of the study, but not supplementation frequency × day of the study or supplementation frequency ($P \geq 0.25$), were detected ($P < 0.0001$) for calf ADG and BW in experiment 1 (Table 2). Regardless of supplementation frequency, the reduction ($P < 0.0001$) in calf ADG from d 56 to 84 (0.48 kg/d) compared with d 0 to 28 (0.75 kg/d) and 28 to 56 (0.87 kg/d) can be partially attributed to the observed decrease in annual ryegrass IVDOM and CP from d 56 to 84, limiting total energy intake of calves. Nonetheless, calf ADG results observed herein agree with those of previous studies conducted at the same location and with similar forage type and concentrate amount (Vendramini et al., 2006; Vendramini and Arthington, 2008; Oliveira et al., 2020). Reducing the frequency of energy supplementation from daily to 3 times weekly either decreased ADG by 10 to 21% (Cooke et al., 2008; Loy et al., 2008; Moriel et al., 2012; Artioli et al., 2015; Moriel et al., 2020) or had no effect on ADG (Drewnoski et al., 2011; Moriel et al., 2016b; Silva et al., 2018). Supporting our hypothesis, calf ADG did not differ between treat-

Table 1. Herbage mass, herbage allowance, CP, and in vitro digestible organic matter (IVDOM) of ryegrass pastures (0.3 ha and 4 calves per pasture per year) grazed by calves provided concentrate supplementation daily or 3 times weekly from d 0 to 84 (experiment 1)[1]

	Day of the study				*P*-value[2]		
Item	28	56	84	SEM	Supp. freq. × day	Supp. freq.	Day
Herbage mass, kg of DM/ha	5117[c]	2462[b]	1465[a]	415	0.97	0.58	<0.0001
Herbage allowance, kg BW/kg ha	4.92[c]	1.98[b]	0.93[a]	0.086	0.95	0.98	<0.0001
CP, % of DM	14.6[a]	18.8[b]	18.0[c]	1.20	0.72	0.23	0.007
IVDOM, %	80.3[c]	67.5[b]	63.6[a]	3.87	0.69	0.46	<0.0001

[a–c]Within a row, means with different superscripts differ ($P \le 0.05$).

[1]Herbage mass was determined using the double sampling technique (Gonzalez et al., 1990). Herbage allowance was calculated as the average herbage mass per pasture by the total calf BW on each respective pasture (Sollenberger et al., 2005). Treatments were randomly assigned to pastures on d 0 (4 pastures per treatment per year) and consisted of calves offered the same weekly concentrate DM amount (1% of BW × 7 d), which was divided into equal amounts and offered either daily (7×) or 3 times weekly (3×; Mondays, Wednesdays, and Fridays) at 0800 h.

[2]Supp. freq. = supplementation frequency.

ments and were 0.72 versus 0.88 kg/d from d 0 to 28 ($P = 0.64$), 0.91 versus 0.82 kg/d from d 28 to 56 ($P = 0.47$), and 0.48 versus 0.49 kg/d from d 56 to 84 ($P = 0.94$) for 7× and 3× calves, respectively. Discrepancies among these studies likely reflect the differences in supplement composition, breed, sex, and forage species and quality, and the potential interactions among these factors (Artioli et al., 2015).

Effects of day of the study, but not supplementation frequency × day of the study or supplementation frequency ($P \geq 0.23$), were also detected ($P < 0.0001$) for plasma concentrations of glucose and urea N of calves from d 0 to 84 (Table 2). Plasma concentrations of glucose increased with greater energy intake (Cappellozza et al., 2014). Plasma concentrations of urea N were positively correlated with rumen-degradable protein intake and rumen concentrations of ammonia (Hammond, 1997), and circulating concentrations between 11 to 15 mg/dL are considered optimal for growing beef calves (Byers and Moxon, 1980). Regardless of supplementation frequency, plasma

Table 2. Body weight and blood plasma urea N and glucose of calves grazing ryegrass pastures (0.3 ha and 4 calves per pasture per year) and provided concentrate supplementation daily (7×) or 3 times weekly (3×) from d 0 to 84 (experiment 1)[1]

	Day of the study				*P*-value[3]		
Item[2]	28	56	84	SEM	Supp. freq. × day	Supp. freq.	Day
BW, kg							
3×	113	136	140	4.2	0.43	0.81	<0.0001
7×	111	137	145	4.2			
Plasma urea N, mg/dL							
3×	7.38	9.94	10.9	0.808	0.37	0.71	<0.0001
7×	5.53	10.6	12.8	0.808			
Plasma glucose, mg/dL							
3×	76.2	73.8	63.6	4.81	0.23	0.42	<0.0001
7×	71.5	80.4	56.8	4.73			

[1]Treatments were randomly assigned to pastures on d 0 (4 pastures per treatment per year) and consisted of calves offered the same weekly concentrate DM amount (1% of BW × 7 d), which was divided into equal amounts and offered either daily (7×) or 3 times weekly (3×; Mondays, Wednesdays, and Fridays) at 0800 h.

[2]Calf BW and plasma data obtained on d 0 did not differ ($P \geq 0.65$) between treatments but were included in the model ($P \leq 0.02$) to covariate-adjust calf BW and its respective plasma data.

[3]Supp. freq. = supplementation frequency.

Table 3. Forage and total dry matter (DM) intake of calves provided ryegrass hay and concentrate supplementation daily (7×) or 3 times weekly (3×) from d 84 to 105 (experiment 2)[1]

	Supplementation frequency			*P*-value[3]		
Item[2]	7×	3×	SEM	*P*-value[4]	Supp. freq. × day	Supp. freq.
Forage DM intake, % of BW						
Tues., Thurs., Sat., Sun.	1.75	1.74	0.111	0.90	<0.0001	0.002
Mon., Wed., Fri.	1.80	1.28	0.111	<0.0001		
P-value[5]	0.50	<0.0001				
Total DM intake, % of BW						
Tues., Thurs., Sat., Sun.	2.71	1.75	0.073	<0.0001	<0.0001	0.16
Mon., Wed., Fri.	2.76	3.51	0.073	<0.0001		
P-value[5]	0.48	<0.0001				

[1]On d 84, a subsample of calves (6 steers and 6 heifers per treatment in year 1; 5 steers and 5 heifers per treatment in year 2) were randomly selected and assigned to 1 of 24 individual concrete floor pens (18 m^2 per pen) in a fully covered drylot facility to evaluate their daily forage and total DM intake (concentrate + hay) and total apparent DM digestibility. From d 84 to 105, calves continued to receive their previous respective frequency of concentrate supplementation (7× or 3×) and were provided daily free-choice access to ground ryegrass.

[2]Forage and total DM intake were determined on days when only 7× calves received supplementation (Tuesday, Thursday, Saturday, and Sunday) and days when both 7× and 3× calves received concentrate supplementation (Monday, Wednesday, and Friday).

[3]Supp. freq. = supplementation frequency.

[4]*P*-value for the comparison of treatment within day.

[5]*P*-value for the comparison of day within treatment.

concentrations of glucose did not differ (P = 0.33) between d 28 and 56 (73.9 vs. 77.0 mg/dL) but decreased (P = 0.0003) from d 56 to 84 (77.0 vs. 60.2 mg/dL), reflecting the reduction in ryegrass IVDOM from d 28 to 84. Plasma concentrations of urea N increased (P = 0.0002) from d 28 to 56 (6.45 vs. 10.2 mg/dL, respectively) and did not differ (P = 0.17) between d 56 and 84 (10.2 vs. 11.8 mg/dL, respectively), likely due to the increased ryegrass CP concentration from d 28 to 56 and the slight reduction (perhaps biologically insignificant) in CP concentration from d 56 to 84 (Table 1). However, plasma urea N observed herein was slightly or significantly below the optimal levels recommended for growing calves (Byers and Moxon, 1980). These outcomes for plasma urea N were unexpected. Previous studies observed that early-weaned calves grazing ryegrass and supplemented with concentrate at 1% of BW achieved plasma concentrations of glucose between 78 to 81 mg/dL and plasma concentrations of urea N above 25 mg/dL, indicating that rumen-degradable protein and total CP were consumed in excess (Oliveira et al., 2020).

Decreasing the frequency of concentrate supplementation led to simultaneous fluctuations in nutrient intake and plasma concentrations of metabolites associated with energy and protein metabolism (Moriel et al., 2012, 2020). For instance, plasma concentrations of glucose and urea N remained stable throughout the week for beef heifers offered daily concentrate supplementation. However, when heifers received concentrate supplementation 3 times weekly, plasma concentrations of glucose increased whereas plasma concentrations of urea N decreased on days when concentrate was not provided compared with days when concentrate was provided to all heifers (Moriel et al., 2020). In the present study, plasma samples were collected 4 h after morning supplementation and only on days when concentrate supplementation was provided. This approach was selected to correspond with the peak of ruminal fermentation and end products release after concentrate intake (Moriel et al., 2012), as well as due to the distance between pastures and cattle processing facility. Therefore, it remains possible that the lack of treatment effects on plasma concentrations of glucose and urea N can be attributed to the timing of blood sampling rather than to the lack of effects of supplementation frequency on circulating metabolites, as extensively reported by our group (Moriel et al., 2012; Artioli et al., 2015; Silva et al., 2018; Moriel et al., 2020).

Fluctuations in nutrient intake following reductions in frequency of concentrate supplementation reported above occur because of the effects of concentrate consumption on forage digestibility (substitution effects). In experiment 2, effects of supplementation frequency × day of the study were detected ($P < 0.0001$) for forage and total DM intake. On days when concentrate supplementation was provided to both 7× and 3× calves (Monday, Wednesday, Friday), forage DM intake decreased by 29% and total DM intake increased by 27% for 3× versus 7× calves (Table

3). On days when concentrate supplementation was provided only to 7× calves (Tuesday, Thursday, Saturday, Sunday), forage DM intake did not differ between treatments, but total DM intake was 35% less for 3× versus 7× calves (Table 3). Therefore, overall forage DM intake was 15% less for 3× versus 7× calves (1.51 vs. 1.78% of BW, respectively; $P = 0.002$), whereas total DM intake did not differ between 3× and 7× calves (2.63 vs. 2.73% of BW, respectively; $P = 0.16$), which, combined, explain the slight reduction observed for in vivo apparent digestibility between 3× versus 7× calves (85.3 vs. 86.5%, respectively; $P = 0.007$). Supplements rich in nonstructural carbohydrates reduce pH and growth of fibrolytic bacteria, leading to compromised digestibility and DM intake with greater substitution effects at higher levels of concentrate supplementation (Horn and McCollum, 1987; Kunkle et al., 2000). However, the results observed for total DM intake, combined with the biologically insignificant differences reported for in vivo apparent digestibility in experiment 2, support the lack of effects of supplementation frequency on calf ADG and BW from d 0 to 84 and BW change from d 84 to 105 (17 vs. 19 kg for 3× and 7× calves, respectively; $P = 0.20$) and agree with our previous results (Artioli et al., 2015; Silva et al., 2018).

APPLICATIONS

Decreasing the frequency of weekly concentrate DM supplementation (1% of body weight × 7 d) from daily to 3 times weekly (Monday, Wednesday, Friday) did not influence growth performance or circulating concentrations of glucose and urea N of early-weaned beef calves during a grazing period (experiment 1). Despite the slight reduction in in vivo apparent digestibility and annual ryegrass DM intake, reducing the frequency of concentrate supplementation from daily to 3 times weekly did not alter body weight change during a drylot period (experiment 2). Hence, feeding costs can be reduced by providing concentrate supplementation 3 times weekly to early-weaned beef calves consuming annual ryegrass, without detrimental effects to their overall growth performance.

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