

Conserved forage-based systems for backgrounding weaned beef calves¹

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ABSTRACT: A 45-d backgrounding study was conducted to compare animal performance, forage nutritive value, digestion dynamics, and diet costs of conserved forage systems for weaned beef calves. One hundred and eight weaned Angus × Simmental beef calves (initial BW 279 ± 34 kg) were randomly assigned to one of three diets ($n = 3$ pens/treatment): 1) free-choice annual ryegrass (**RB**; cv. ‘Marshall’) baleage and 4 kg of a 50/50 mixture of pelleted soybean hulls and corn gluten feed, 2) free-choice Tifton 85 bermudagrass (**BH**) and 3 kg of a 50/50 mixture of pelleted soybean hulls and corn gluten feed, or 3) free-choice corn silage (**CS**; cv. Pioneer P1662YHR) and 2 kg of a 85% cracked corn and 15% cottonseed meal mixture. Diets were formulated to achieve a target gain of 0.9 kg/d based on the NRC (2000) requirement for a 270 kg growing calf. Animal performance (initial BW, final BW, and ADG) was measured on days 0 and 45 of the study. Forage nutritive value and an in vitro digestion trial were conducted to evaluate supplementation effects on forage diet digestion dynamics. Data were analyzed using PROC Mixed in SAS 9.4 as a completely randomized design. Pen was the experimental unit. Mean initial and final BW of

the animals did not differ ($P = 0.50$ and $P = 0.99$, respectively) across treatments. Calf ADG for RB, BH, and CS diets were 0.61, 0.72, and 0.72 kg/d, respectively, and did not differ across treatments ($P = 0.57$). Based on these results, these forage options supported a similar level of gain when used for backgrounding beef calves. Forage in vitro DM digestibility differed 48 h after digestion, and BH + 50:50 had greater 48-h digestibility than when unsupplemented, which may be related to complementary forage-supplement interactions. In diets containing RB and CS, digestibility was greater with no supplementation at the 48-h time point. These data support the observation that supplementation type and level influence conserved forage diet digestibility compared with forage alone. The cost of feeding a baleage-based diet in this system was higher (\$1.37/d) than CS or BH diets (\$1.02 and \$0.95/d, respectively). Results suggest that RB baleage-based diets may support a similar level of gain to BH or CS diets in growing beef calves, but supplement type, level, and ration costs should be evaluated when determining cost-effective backgrounding options in the Southeastern United States.

Key words: annual ryegrass, baleage, bermudagrass, corn silage, coproduct feeds

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INTRODUCTION

There are over 9.8-million head of cattle and calves in the Southeastern United States, with calves being primarily sold at weaning. Depending on cattle market cycles, backgrounding calves for a 45- to 60-d period post weaning may be a profitable alternative. Backgrounding provides an opportunity for calf identification, castration and dehorning, administration of vaccinations, and training the animal to eat from feed bunks and drink from a clean water source (Peterson et al., 1989). Avent et al. (2004) suggested that producers might consider keeping weaned calves on-farm for a minimum of 45 d post weaning to take advantage of greater seasonal feeder calf prices later in the season. Midsummer- and fall-weaning programs in the Southeastern often coincide with periods of low-quality forage available for grazing or the fall forage production gap in the region. Producers commonly wean and background calves in a drylot feeding setting or place calves onto dormant pastures and feed hay with a supplement and mineral mix. In either method, conserved forages are the primary forage source in these diets. However, frequent rainfall and high humidity may limit the ability for a 3- to 5-d window to adequately cure hay in the Southeast, which may decrease forage quality due to prolonged harvest frequency between cuttings. Alternative harvest methods such as silage or baleage production require less drying time, which may allow for earlier harvests when quality is greater and weather conditions are not favorable for curing. McCormick et al. (2002) reported that annual ryegrass (RB; *Lolium multiflorum*) is one of the most successful forage species for making baleage in the Southeastern region because of its high forage quality, which provides a good environment for fermentation when baled between 40% and 60% moisture. To date, there have been few studies evaluating the animal performance, forage nutritive value dynamics, and diet costs of conserved forage-based diet systems for backgrounding calves in the Southeastern United States. This is especially important as forages conserved through ensiling have been previously shown to result in reduced DMI compared with forage conserved by nonensiling processes (Gordon et al., 1960; Hawkins et al., 1970; Bergen, 1972), which may influence feed management recommendations during the backgrounding phase for beef cattle operations. The objectives of this study were to 1) provide a system-level comparison of animal performance and ration costs of conserved forage-based diets for backgrounding

beef calves and 2) evaluate nutritive value characteristics and in vitro digestion dynamics of these systems.

MATERIALS AND METHODS

Animal and Feed Management

A 45-d backgrounding trial was conducted at the E. V. Smith Research Center in Shorter, Alabama from September 15 to October 30, 2015. All procedures were previously reviewed and approved by the Auburn University Institutional Animal Care and Use Committee (PRN 2015–2710). One hundred and eight Angus × Simmental calves were weaned on September 2, 2015, placed in feeding pens, and given ad libitum access to bermudagrass (BH) hay and water. Calves were sorted by sex, weight (initial BW 283 ± 16 kg), age, and randomly assigned to one of three diet treatments on September 8 for a 7-d diet acclimation period ($n = 9$ pens). Nine feeding pens were used for the study with three pens per treatment. Twelve calves were allocated per pen (six heifers and steers, respectively) to allow for 0.45 m of bunk space per calf. Individual pen space was 286 m² with a 72 m² covered loafing area and inline feed bunks 6.7 m in length. Treatments consisted of three conserved forage diets (% DM basis): 1) Free-choice annual RB (cv. ‘Marshall’) baleage and 4 kg of a 50/50 mixture of pelleted soybean hulls and corn gluten feed, 2) Free-choice Tifton 85 BH and 3 kg of a 50/50 mixture of pelleted soybean hulls and corn gluten feed, and 3) Free-choice corn silage (CS; cv. Pioneer P1662YHR) and 2 kg of a 85% cracked corn and 15% cottonseed meal mixture. Supplemental feeds were selected to reflect readily available feed sources in the Southeast and used to develop backgrounding diet systems that are reflective of local industry practice. Diets were formulated to achieve a target gain of 0.9 kg hd⁻¹ d⁻¹ based on the NRC (2016) requirement for a 270-kg growing calf with an expected DMI of 2.5% of BW per day. Supplemental feed level was determined based on expected animal nutrient requirements and forage quality analysis for each treatment. Diets were formulated to be isocaloric, and composition is listed in Table 1. Forage was fed in bunk line feeders, and 30% excess was added to expected DMI requirements to ensure cattle had ad libitum access to the forage component of individual diets. Feed supplements for each treatment were top-dressed on forage in the bunk daily. Calves were placed in pens on day -5 to allow for acclimation to the diet.

Table 1. Chemical composition of conserved forages and coproduct supplements fed during a 45-d backgrounding trial for weaned beef calves

Item	RB*	CS	BH	50/50 SH: CGF	85/15 CC:CSM	SE
Moisture, % as-fed	59.3	72.0	14.8	9.5	13.1	—
Nutrient analysis [†]						
CP	10.0a	6.9c	9.9b	16.2	13.2	0.35
NDF	56.5b	38.0c	67.0a	51.2	19.4	2.78
ADF	34.9a	19.9b	35.0a	27.9	10.0	2.27

*RB = annual ryegrass baleage harvested in the boot-to-early dough stage; CS = corn silage harvested in the milk stage; BH = Tifton 85 bermudagrass hay harvested on a 4-wk frequency from May through June 2015; 50/50 SH:CGF = 50% mixture of soybean hulls and 50% corn gluten feed, respectively; 85/15 CC:CSM = 85% mixture of cracked corn and 15% mixture of cottonseed meal, respectively.

[†]Values reported on a % DM basis.

^{a,b,c}Within a row, means without common superscripts differ ($P < 0.10$).

Feed was weighed in and out of bunks on a daily basis throughout the duration of the feeding trial. Estimated forage intake per pen is reported in the RESULTS AND DISCUSSION. Cattle had access to water and mineral (Wind and Rain All Season 7 Complete, Purina, Shoreview, MN) ad libitum for all treatments during the evaluation. Animal BW was measured on days -7, 0, 21, and 45 during the backgrounding trial to evaluate BW gain and ADG. Animals were weighed in the morning before being fed. Initial BW, final BW, and ADG are reported in Table 3.

Forage Management and Laboratory Analysis

Annual RB was planted on a 6-ha field into prepared seedbed on October 30, 2015. At planting, 33-kg N/ha, and P and K were applied according to recommendations from the Auburn University Soil Testing Laboratory (Mitchell and Huluka, 2017). An additional 56-kg N/ha was applied to the area in late January 2015. Annual RB was harvested as baleage in the boot-to-early dough stage on April 22, 2015 and allowed to wilt for 24 h to achieve a moisture level of 40% to 60% prior to baling and wrapping. Moisture range of baleage prior to baling was determined using a microwave test (Stevens et al., 1993). Baleage was wrapped using an in-line wrapper with six layers of polyethylene plastic with a 50% overlap and stored until the time of feeding. Corn was planted on April 1, 2015 and harvested as silage and chopped in the milk stage on July 13, 2015 and stored in polyethylene silo storage bags prior to feeding. CS fertility rates were 200-kg N/ha at planting, and P and K applied according to recommendations from the Auburn University Soil Testing Laboratory (Mitchell and Huluka, 2017). Tifton 85 BH was harvested as hay on a 28-d interval for the study from May to July 2015 and stored in a pole barn until the start of the backgrounding

study. BH hayfields were fertilized in late April 2015 with 112-kg N/ha and P and K according to Auburn University Soil Testing Laboratory recommendations. An additional 112-kg N/ha was applied following harvest in July. For each forage treatment, five core samples were collected from each forage type weekly throughout the 45-d backgrounding period. Samples were composited by forage type and week and transported to the Auburn University Ruminant Nutrition laboratory for storage prior to nutritive value analysis. Baleage and silage samples were freeze-dried using a VirTis Genesis 35L freeze dryer (SP Scientific, Gardiner, NY). Dried samples of all forages were ground to pass a 1-mm screen using a Wiley Mill (Thomas Scientific, Swedesboro, NJ) before nutritive value analysis. During the feeding evaluation, hand-grab samples of baleage, silage, and hay were taken each day at the morning feeding. Samples from each forage type within week were composited and used for laboratory analyses. Forage samples from each week were analyzed for concentrations of NDF and ADF according to the procedure described by Van Soest et al. (1991) using an ANKOM 2000 Automated Fiber Analyzer (ANKOM Technology, Macedon, NY). Forage concentration of CP was analyzed according to the Kjeldahl procedure (AOAC, 1990) using a FOSS Kjeltac 8200 (FOSS, Eden Prairie, MN). Forage CP was then determined as $N \times 6.25$.

In Vitro DM Digestibility Trial

An in vitro fermentation trial was conducted with each forage type and diet used in the feeding study using 75 mL flasks as described in a protocol by Lourenco et al., 2017. Treatments for the in vitro study included RB, BH, or CS with or without supplemental feed. Initial sample weight per incubation flask was 0.75 g (forage plus supplement). The amount of each diet added to the incubation

jars was estimated based on a 272 kg growing steer consuming 2.5% of their BW per day in DM with a target ADG of 0.9 kg/d. Supplemental feed type and amount were representatives of level provided to calves in the 45-d feeding trial. Treatments were organized in a 3 × 2 factorial design as three forage types with or without supplement and are described in Table 2. Diets were subjected to in vitro digestion for seven time points: 0, 3, 6, 12, 18, 24, and 48 h to evaluate in vitro DM and NDF digestibility.

Rumen contents were collected at the Auburn University College of Veterinary Medicine from a cannulated Holstein cow that was offered access to BH hay ad libitum and supplemental feed limit fed twice a day. This feed consisted of a 15% CP supplement consisting of soy hull pellets, corn gluten feed, and whole cottonseed, plus 8 oz of Meagalac (Arm and Hammer Nutrition, Princeton, NJ). Rumen contents were transported to the Auburn University Ruminant Nutrition laboratory in prewarmed thermos containers where it was strained through cheesecloth to remove particulates. Digestion flasks (75 mL, glass Erlenmeyer flasks) were prepared for the study with 0.75 g of each diet, 16.5 mL of rumen fluid, and 33 mL of phosphate-carbonate buffer (pH 6.8; McDougall's buffer). Each mixture was flushed with CO₂ and sealed with a rubber stopper before being placed in a 39 °C water bath incubator (ThermoFisher Scientific, Waltham, MA) for 48 h. Stoppers were retrofitted with a three-way valve and 50 mL syringe and needle to remove gas pressure throughout the study. Each treatment was run in duplicate over the respective time points during the 48-h observation period ($n = 84$ flasks). Digestion flasks were removed at the respective time point, and contents of the flask were transferred to plastic

Table 2. In vitro digestibility trial forage diet composition*

Treatment [†]	Forage (g)	Supplemental feed (g)
RB	0.75	—
CS	0.75	—
BH	0.75	—
RB + 50:50	0.51	0.24
CS + CC:CSM	0.63	0.12
BH + 50:50	0.52	0.23

*Diets are based on a 250-kg steer consuming 2.5% BW in DM. Supplemental feed inclusion is estimated based on amount offered to animals in the 45-d backgrounding trial.

[†]RB = annual ryegrass baleage harvested in the boot-to-early dough stage; CS = corn silage harvested in the milk stage; BH = Tifton 85 bermudagrass hay harvested on a 4-wk frequency from May through June 2015; 50:50 = 50% mixture of soybean hulls and 50% corn gluten feed, respectively; CC:CSM = 85% mixture of cracked corn and 15% mixture of cottonseed meal, respectively.

Nalgene bottles and placed in a freezer (−20 °C) to stop fermentation. Bottles were allowed to thaw at room temperature 3 d later, and diet residues were filtered through a Buchner funnel using Whatman filter paper (Grade 40) and a vacuum pump. Diet residues were placed in a 50 °C forced-air oven to dry for 48 h. Digestibility at each time point was calculated as the difference between initial sample weight and residual weight. A NDF analysis was conducted on sample residue to remove microbial debris and determine in vitro DM digestibility and NDF digestibility.

Diet Cost Analysis

Forage DM cost per ton and daily ration costs per calf were calculated for each treatment. Data from the Alabama Weekly Hay Report and Alabama Weekly Feedstuff Report (USDA AMS, 2018) for the time of the study for each forage and supplement were used to determine a ration cost for each diet (Table 3) per head per day.

Statistical Analysis

Data from the feeding trial were evaluated using the PROC MIXED procedure of SAS 9.4. The experiment was a completely randomized design with pen as the experimental unit during the 45-d backgrounding study. Diet was considered a fixed effect. The PDIFF option of LSMEANS was used to separate treatment means, and because of the low number of animals, differences were declared when $P < 0.10$ for all analyses. A first-order autoregressive covariance structure was used, and calf sex was included as a covariate. Regression analysis was performed with in vitro digestibility data to evaluate changes in fermentation metrics over the incubation times up to 48 h.

Table 3. Animal performance, cost of forage DM per metric ton, and daily ration costs for growing beef calves from conserved forage diets during a 45-d preconditioning trial

Item	RB*	CS	BH	SE
Initial BW, kg	287	282	282	8.2
Final BW, kg	314	315	314	5.9
ADG, kg/d	0.61	0.72	0.73	0.12
Forage DM cost per metric ton	137	160	123	—
Diet costs (\$/head/day)	1.37	1.02	0.95	—

*RB = annual ryegrass baleage harvested in the boot stage, CS = corn silage harvested in the milk stage, BH = Tifton 85 bermudagrass hay harvested on a 4-wk frequency from May to June 2015.

RESULTS AND DISCUSSION

Animal Performance

There were no differences ($P = 0.33$) in initial BW, final BW, or ADG of beef calves fed annual RB-, CS-, or BH-based rations during the 45-d backgrounding trial (Table 3). Gain per day was between 0.61 and 0.73 kg/d for calves consuming the diets evaluated. Estimated forage intake per pen was 193, 231, and 94 kg/d on an as-fed basis for RB-, CS-, or BH-based rations, respectively, across the 45-d feeding period. As a percentage of calf BW during the trial, estimated DMI was 2.5 for RB, 1.8% for CS, and 2.2% for BH, illustrating that intake was equal to or below the formulated intake of 2.5% of BW per day. This level of intake is sufficient to support ADG of 0.7 kg/d for growing calves, but diet nutrient density at the levels of consumption reported was not sufficient to support the target of 0.9 kg/d. As the silage system had a lower reported DMI, this must be taken into account when making comparative assessments between these backgrounding systems. In fermented feeds, the actual availability of feed protein/nitrogen to the rumen microbiota is often reduced (Bergen et al., 1991). Because of this, a lower DM digestibility in ensiled feedstuffs may occur if no protein supplementation is practiced, which has a depressing effect on observed DMI. Although cottonseed meal was provided as a protein supplement as part of CS-based diets, at the level of intake observed, a combination of low protein intake and availability may have reduced animal gains in this system relative to other reported trials. In a 121 d trial, Young and Kauffman (1978) observed an ADG for growing calves fed a CS-based diet of 1.09 kg/d consuming 2.4% of BW per day in DM. When comparing early boot stage cereal rye (*Secale cereale*) and RB baleage to late-bloom stage rye and RB baleage, BH baleage, and BH hay, Martin et al. (2015) experienced ADGs lower than those observed in the present study at 0.46 kg/d for 60 d for growing beef calves when supplemented with a self-limiting molasses-based liquid protein supplement. The authors reported a mean CP of 12.8% and TDN of 64.5% (DM basis) for boot stage rye and RB. However, Hancock (2010) found that beef replacement heifers fed RB (16.3% CP and 65.9% TDN, respectively) had a greater ADG (0.88 kg/d) than those fed BH or RB hay (16.1% and 14.7% CP; 62.9% and 62.4% TDN, respectively). The values observed for RB in the present study were

lower than those reported in other recent evaluations, which supports the observation that annual RB in this study was in the dough rather than boot stage of maturity at harvest. Coffey et al. (2002) performed a 3-yr study providing ad libitum access to BH supplemented with grain sorghum for growing stocker calves. The authors reported an ADG of 0.71 kg/d across the 3 yr. These data are similar to those observed in the present study when moderate-quality BH was fed. Based on published trials, animal performance from RB may vary, but values similar to or greater than those of traditional CS- or hay-based diets are commonly observed.

Forage Nutritive Value and In Vitro Digestibility

Table 1 shows the nutritive value of each of the forages used in the preconditioning diets in this study. Differences were observed in CP, NDF, ADF, and TDN% among forage types ($P < 0.10$). Forage concentration of CP for RB and BH was greater than CS. This observation fits with expected values for CS, which commonly range from 6.8% to 9.3% CP (Bal, 2006; Martin et al., 2008). Fiber constituents were greater for BH and RB than CS. BH hay and CS quality in this study was similar to those reported in the literature with a comparable harvest frequency. Mandevu et al. (1998) evaluated forage nutritive value characteristics of Tifton 85 BH hay harvested at 3.5 wk and 7 wk in comparison with CS. The authors reported CP values of 15.5% DM at 3.5 wk and 9.0% DM at 7 wk, although fiber constituents were greater in their study than those observed for the 4-wk harvest frequency used in this trial. Forage CP of CS in their trial was 9.3% DM, which is greater than what was observed in the present study at 6.9% DM. Lower CP values in the present study may be attributed to differences in N fertilization and harvest times between the two studies. McCormick et al. (1998) harvested annual RB for baleage in the boot stage and observed greater CP and digestibility values than were seen in this study, which is likely attributed to differences in stage of maturity at harvest. Beef producers often target daily gains of 0.7 to 0.9 kg in preconditioning and stocker systems (Beck et al., 2013). The nutritive value of forage reported in this trial highlights the need for additional supplementation to be provided if gain is to be achieved for growing beef calves, which is illustrated by the level of animal performance observed in the present study.

In vitro DM digestibility of forage diets increased in a quadratic manner with increasing

time of digestion (Figure 1). There were no differences among treatments in IVDMD until the 48 h after digestion (Table 4; $P = 0.02$), which was attributed to greater variation (mean CV of 12% across time points) at these time points. Supplementation of BH increased IVDMD, which illustrates a positive associative effect of fiber-based coproduct supplementation on BH hay digestibility in this study. Highfill et al. (1987) reported that high-fiber supplements such as soy-hulls and corn gluten feed may be less susceptible to negative feed interactions by lessening inhibitory effects on starch digestion and/or avoiding potential shifts in native ruminal microflora. Galloway et al. (1993) suggested that supplementation of growing cattle consuming moderate-quality tropical grass hay with a low-to-moderate level of DE (20 kcal/kg of BW) from corn or soybean hulls may increase digestible OM intake without adverse effects on fiber digestibility. Forage IVDMD decreased with the addition of supplement in BH- and CS-based diets and had a more negative impact on fiber digestibility in these diets. Forage IVDMD values in this study were

consistent with those reported in the literature under similar growing conditions (McCormick et al., 1998; Martin et al., 2008). Overall, forage IVDMD reflects moderate-to-high quality forage used in this study. There were no differences in NDF digestibility for RB or BH with or without supplementation. Forage NDF digestibility of CS with supplementation increased compared with CS alone, which may reduce physical fill in the rumen over time and can allow greater voluntary feed intake (Dado and Allen, 1995).

Diet Costs

Table 3 shows the diet costs for annual RB baleage, CS, and BH hay. Baleage was shown to be more expensive on a per head basis than hay, at \$1.37/d vs. \$0.95/d. Silage was intermediate at \$1.02/d. This diet cost was similar a baleage system from Hersom et al. (2007). The authors reported a diet cost for baleage of \$1.26/d in a split BH hay/baleage system. In drylot feeding systems, such as the one used in the present study, feed costs represent a large proportion of the cost of gain per

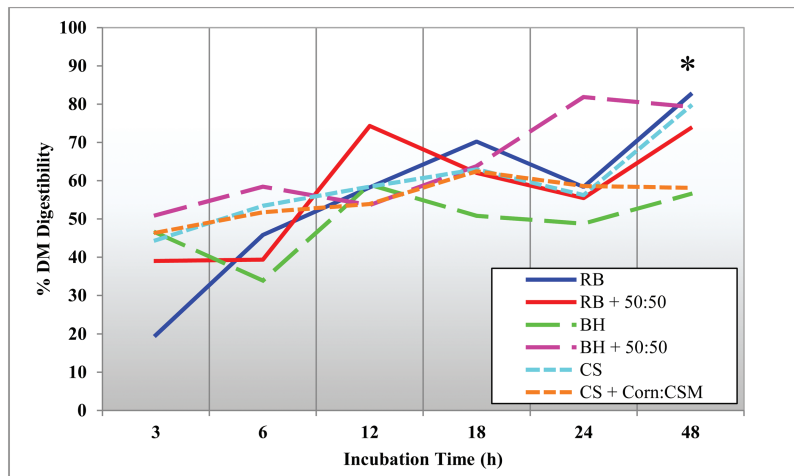


Figure 1. Forage diet in vitro digestion dynamics over a 48-h incubation period. RB = annual ryegrass baleage harvested in the boot-to-early dough stage; CS = corn silage harvested in the milk stage; BH = Tifton 85 bermudagrass hay harvested on a 4-wk frequency from May to June 2015; 50:50 = 50% mixture of soybean hulls and 50% corn gluten feed, respectively; CC:CSM = 85% mixture of cracked corn and 15% mixture of cottonseed meal, respectively. *Means differ $P < 0.02$.

Table 4. IVDMD and NDF digestibility (% DM basis) of conserved forage diets with or without supplementation

Item* %	RB [†]	CS	BH	RB + 50:50	CS + CC:CSM	BH + 50:50	SE	P-value
IVDMD	70.4b	67.8c	52.6d	65.6c	58.4d	80.5a	3.5	0.0158
NDFD	49.9c	55.6b	44.6d	45.9cd	61.8a	44.9d	2.4	0.0001

*Values based on average after 48 h of digestion.

[†]RB = annual ryegrass baleage harvested in the boot-to-early dough stage; CS = corn silage harvested in the milk stage; BH = Tifton 85 bermudagrass hay harvested on a 4-wk frequency from May to June 2015; 50:50 = 50% mixture of soybean hulls and 50% corn gluten feed, respectively; CC:CSM = 85% mixture of cracked corn and 15% mixture of cottonseed meal, respectively.

^{a,b,c,d}Within a row, means without common superscripts differ $P < 0.10$.

head. Producers should evaluate forage and supplementation costs using a partial budget approach in order to develop cost-effective feeding strategies during the backgrounding phase.

SUMMARY AND CONCLUSIONS

Results of this study suggest that diets containing RB-based diets can support gains in growing beef calves similar to those of BH or CS, although observed DMI was lower for CS than baleage or hay systems. Conserved forages fed in this study were moderate in quality. Forage stage of maturity at harvest is a key factor influencing forage nutritional value, intake, supplementation type, and level in this system. If forage nutritive value alone meets the target daily growth requirements of weaned calves, additional supplementation may not be needed. However, if forage nutritive value is deficient, as was the case in this study, calves may benefit from supplementation. Choice of supplement type (fiber vs. starch-based) and level may influence forage digestion dynamics. Fiber-based supplementation approaches had a positive associative effect on dry hay but not high-moisture forage diets. Forage digestion kinetics and protein fraction characterization may provide useful information for selecting and adjusting feeding regimens in drylot preconditioning programs in the Southeastern United States. Beef producers considering the use of annual RB baleage should compare the costs of their current production system to additional considerations needed to make and feed high-quality high-moisture forages to determine the viability of its use as an alternative feeding system during the backgrounding phase.

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