

Pre-conditioning beef calves with high moisture forages and co-product feeds

by

Erin Morgan Forte

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Approved by

M. Kimberly Mullenix, Chair, Assistant Professor of Animal Sciences
Werner Bergen, Professor of Animal Sciences
Deacue Fields, Department Chair and Professor of Agricultural Economics and Rural Sociology

ABSTRACT

A 45-d backgrounding study was conducted at the E.V. Smith Research Center in Shorter, AL to determine animal performance differences of pre-conditioned beef calves fed annual ryegrass (*Lolium multiflorum*) baleage, bermudagrass (*Cynodon dactylon*) hay, or corn (*Zea mays*) silage-based diets. Annual ryegrass (cv. Marshall) was harvested for baleage on 22 Apr 2015 at the late boot stage of maturity. The forage was allowed to wilt for 48 h until it achieved 60% moisture, baled and wrapped. Tifton 85 bermudagrass used for the study was harvested at a 4 to 5 wk interval in early summer 2015. Based on forage quality, calves were supplemented with an energy-protein based ration (50:50 soybean hulls and corn gluten feed for baleage and hay treatments, and 85% corn, 15% cottonseed meal mix for corn silage treatments) to target 0.7 kg/day ADG according to NRC (2000) recommendations. The 45-d background trial began on 9 September 2015 after animals were sorted and acclimated to the diets. 108 weaned calves [heifers (n = 54; mean initial BW 283 kg) and steers (n = 54; mean initial BW 284 kg)] were placed into nine pens (n = 12/pen, 3 pens/treatment). Sex was distributed evenly across treatments. Animals were weighed on d 0, 22, and 44, and the study concluded on 23 October 2015. Animal performance measures were analyzed using PROC Mixed in SAS 9.4 as a completely randomized design, and 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. Average daily gain for annual ryegrass baleage, bermudagrass hay, and corn silagebased diets were 0.61 kg/day, 0.72 kg/day, and 0.72 kg/day, respectively, and did not differ across treatments ($P = 0.57$). Based on these results, these forage options achieved a similar level of gain when supplemented for pre-conditioning beef calves. *In vitro* dry matter digestibility (DMD) of diets

used for pre-conditioning calves did not differ across a six-time point evaluation, and had an IVDMD of 70.1% at the 48 h digestion point. Results of the digestion trial indicate that supplementation of stored forages did not improve diet digestibility compared to forage alone. Economic analysis revealed that the cost of feeding a baleage diet in this system was higher than that of corn silage or bermudagrass diets with a cost of \$1.37/hd/d compared to \$1.02 and \$0.95/hd/d, respectively.

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LIST OF ABBREVIATIONS

ADG	Average daily gain
BH	Bermudagrass hay
CS	Corn silage
NIR	Near infrared spectrophotometer
RB	Ryegrass baleage
WSC	Water soluble carbohydrates

I. REVIEW OF THE LITERATURE

Pre-conditioning

Pre-conditioning cattle is a practice used by beef cow-calf producers to prepare calves to enter a feedlot system. Pre-conditioning usually occurs after weaning and consists of training calves to eat from a bunk and drink from a trough, as well as vaccination protocols, dehorning, and castrating bull calves (Parish et al., 2010). While health of the calves is generally the main focus of these protocols, the animals, as well as the producers, benefit from improved feed efficiency and improved carcass traits (Ward et al., 2007). Most pre-conditioning programs last a minimum of 45 days, with some lasting up to 60 (Mathis et al., 2013). Pre-conditioning programs increase the value of weaned calves because of improved growth and overall health. Animals from the Southeast are viewed as high risk based on experiences in the feedlot with calves from this region (Thomson and White, 2006), as well as a lack of basic management practices. As many as 49% of cattle originating in the Southeast reach feedlots without having been dehorned (Parish et al., 2010).

Nutrition is a major focus of pre-conditioning programs in order to achieve weight gain. Beef calves can be fed a variety of different diets; however, there are a few strategies that are most common to the Southeast. These strategies generally are separated into grazing and non-grazing systems. Preconditioned beef calves can be only grazed, grazed with a supplement, or fed roughage and concentrate in a drylot system (Lalman et al., 2002). Calves being grazed, with or without supplement, benefit from any standard grazing system in the Southeast where quantity and quality of the forage are not limiting. Because the Southeast has a mild climate and high rainfall, there are many forage options for grazing cattle. The predominant forage systems

consist of warm-season perennial grasses overseeded with legumes and cool season annual grasses, or tall fescue-based systems. Warm-season perennial grasses adapted to the region include bermudagrass and bahiagrass. In overseeded warm-season grass systems, cool-season annual grasses such as ryegrass and small grains are often used to extend the grazing season into the winter and spring months. The addition of legumes to these mixtures may further diversify forage growth distribution and provide additional grazing.

Supplementation strategies are regularly used to increase gain and/or stocking rate capacity in pre-conditioning systems using grazed or stored forages. Horn et al. (1995) found that both high-starch and high-fiber energy supplementation on wheat pasture resulted in an increased average daily gain by 0.15 kg/steer compared with mineral supplementation on grazed pasture alone. Animals fed in a bunk are usually in a drylot system fed a diet containing roughage and concentrates. Pasture systems are considered less stressful and lower cost, although dry-lot systems result in greater gain and an easier adjustment to a feedlot. According to Mathis et al. (2008), dry lot preconditioned cattle gained 0.14 kg/d more than pasture preconditioned cattle, although the pasture preconditioned calves resulted in a higher profit of \$44.59/hd. Once these calves arrived at the feedlot, there were no differences between the two feeding systems in overall average daily gain, finished body weight, days on feed, or carcass characteristics.

Stored Forage Systems in the Southeast

During the pre-conditioning phase, forages are typically used as part of the base diet and development program for growing calves during a 45 to 60 day period. The forage portion of the diet can be provided through either grazing actively growing or stockpiled forage, or by providing harvested forages such as hay, silage, or baleage. Producers utilizing a pre-

conditioning or stocker system can benefit from the use of harvested forages. Harvested forages can supplement pasture systems that are not meeting animal requirements on their own, especially during the forage gap seen between warm and cool-season forages during the fall in the Southeast.

Howard et al. (2011) defined hay as harvested forage preserved by drying generally to a moisture content of less than 200 g kg⁻¹, and silage as forage harvested and preserved at high moisture content (generally > 500 g kg⁻¹) by organic acids produced during partial anaerobic fermentation. Baleage is defined as harvested forage ensiled at a moisture content of less than 500 g kg⁻¹. Baleage and haylage are often terms that are used interchangeably, but generally constitutes a high-moisture forage that has been harvested, baled, and wrapped in plastic (Mullenix, 2014). Differences exist between stored forage systems relative to their nutritive value potential and storage losses. Hay is the predominant stored forage type used in the southeastern US. The most common forages used for hay production in this region include bermudagrass, bahiagrass, dallisgrass, johnsongrass, small grains, annual ryegrass, and tall fescue (Ball et al., 2015). Significant dry matter and quality losses in hay can occur during the harvesting, drying, storage, and feeding process depending on the methods used. Many producers in the Southeast store hay outside, which results in dry matter deterioration and animal waste at the time of feeding. Ball et al. (2015) stated that during the first year of storage, hay stored on the ground had a dry matter loss of 43%, on a wooden rack had a dry matter loss of 31%, on a wooden rack covered with plastic had a dry matter loss of 12%, and in a pole barn a loss of 2%. The authors also reported the loss as a result of animal refusal with the previously listed storage methods as 66, 38, 14, and 3% on a dry matter basis, respectively. Storage losses of hay were reported by McCormick (2011) in comparison to baleage as well. The dry matter loss

for outdoor-stored warm-season grass hay was significantly greater than the losses for the barn-stored hay and baleage with values of 12.8%, 2.9%, and 0.3%, respectively.

Hay storage methods can influence forage nutritive value. McCormick et al. (2011) compared bahiagrass as outdoor-stored hay (OSH), barn-stored hay (BSH), and baleage (BAL) when fed to lactating dairy cattle. These forages were fed as part of a 42-day feeding trial. Differences in the acid detergent fiber (ADF) of these forages were observed. Outdoor-stored hay had a significantly greater ADF at 44.4% when compared to both barn-stored hay (38.8%) and baleage (39.5%). Neutral detergent fiber (NDF) was significantly greater for OSH than BSH and BAL with values of 74.9%, 69.5%, and 70.1%, respectively. Net energy for lactation (NE_L) was significantly lower for OSH than BSH and BAL with values of 1.17, 1.32, and 1.32 Mcal/kg, respectively, illustrating nutrient dry matter loss and potentially reduced animal use with traditional outdoor storage methods of hay.

Silage is a popular harvested feed among cattle producers. In the Southeast, corn and sorghum silage are the most common types produced as livestock feed. Corn silage is well known for its use in large dairy farms across the US. This is mostly because corn silage has been shown to increase milk yield and milk protein values (Benchaar et al., 2007, Gaus et al., 2011). In the beef industry, corn silage is also used among larger beef operations (greater than 100 head) in the Southeast. In order to get the best possible quality silage, corn must be harvested at 60-70% moisture (Bagg et al., 2013). Using the milk line to estimate maturity, this moisture content is achieved in the late milk or early dent stage (Ashley, 2001). Corn silage varies in nutrient content based on maturity at harvest, but typically has an ADF value of 25.5% and an NDF value of 42.9% (NRC, 2016). Once corn silage is cut, chopped and placed in the silo, bag, or pit, the plant cells continue to respire, causing the product to enter into a period known as

Phase I, eliminating remaining oxygen in the bag/pit to cause an entry into an anaerobic state. It is desirable for as much oxygen to be eliminated before storage as the aerobic bacteria present on the plant particles consume water soluble carbohydrates (WSC) that would otherwise be available for lactic acid bacteria to utilize during the fermentation process. The respiration process also creates water and heat. Excessive heat production can reduce forage digestibility and protein availability. Phase I is complete when the oxygen is eliminated from the silage mass. When silage is cut, stored at an appropriate moisture content and stage of maturity, and sealed, this phase lasts a few hours. Phase II begins when the acetic acid producing-bacteria begin to populate the silage. These bacteria ferment WSC into acetic acid. Acetic acid is important as it triggers the initial drop in pH required to initiate other fermentation processes. Phase II usually lasts 24 to 72 hours and ends when pH drops below 5.0 and acetic acid producing-bacteria numbers begin to decline. Phase III is the growth of lactic acid bacteria after the acetic acid bacteria are reduced. In Phase IV, these lactic acid bacteria ferment WSC into lactic acid, which is the most desirable fermentation end-product in silage production. Phase IV ends when the silage reaches a pH of 4.0 about 21 days after storage (Jones et al., 2004 and Schroeder, 2004). Bacteria can no longer grow and the silage is considered stable.

Segers et al. (2014) compared weight gain in beef steers fed corn silage supplemented with dried distillers grains plus solubles, corn gluten feed, or soybean meal plus ground corn over an 84 day stocking period. Calves gained 1.08 kg/hd/d for the silage supplemented with corn gluten feed or soybean meal plus ground corn and 0.94 kg/hd/d for silage supplemented with dried distillers grains plus solubles. This study shows that silage can support desirable gain during the stockering period when supplemental crude protein is provided.

Baleage production

With new technology available for making and preserving high-moisture forages, there is increasing interest among producers in baleage production. In the Southeast, there are several forage options for making baleage. Sears et al. (N.D.) suggested that the predominant cool-season grass options available in the region include annual ryegrass, small grains such as oat, wheat, rye, and triticale, and tall fescue. Warm-season grass options include annuals such as sorghum, sudangrass, sorghum x sudangrass crosses, pearl millet, crabgrass, and perennials such as bahiagrass and bermudagrass. Legumes can also be utilized for baleage including alyceclover, red, white, crimson, and arrowleaf clover, cowpeas, and forage soybeans. However, more often these species are grown in mixtures with forage grasses to add species diversity and quality to baleage products. Brassicas such as rape, turnips, and kale may be used in baleage systems, although limited research has been done with these species. Regardless of the forage type, each species must be cut at a time where yields are sufficient for producing adequate forage dry matter, but plant maturity is at an appropriate stage to make baleage that is of sufficient quality for supporting livestock production goals. The general recommendation for harvest is at 10% bloom for legumes and the boot stage of growth for grass crops. Small grains should be cut in the flag leaf stage, as they tend to lose forage nutritive value very quickly as they mature. In forage mixtures, the target harvest time should be based on which forage crop matures first, although yield potential of other forages in the mixture may be compromised under these conditions, so mixtures should be considered with these factors in mind (McCormick, 2008).

Harvesting grasses and legumes for baleage requires standard equipment, including a mower, rake, high-moisture baler, tractor, bale spear, and wrapper (Sears et al., N.D.). When the forage is cut, a mower-conditioner is recommended for harvesting since it produces a relatively uniform

cut and exposes more surface area on the forage for the microbes to attach and begin fermentation. This can cause a faster drop in pH and more efficient ensiling. After cutting, if the forage is over 60% moisture, it must be allowed to wilt to the 50 to 60% moisture range. Wilting times needed to reach this target range vary depending on forage species, weather conditions, and original DM percentage. Wilting is especially important when cutting cool-season grasses since they are often in a lush, vegetative stage of growth at the time of harvest. Jones et al. (2004) noted that small grains often consist of as much as 85% moisture at the time of harvest (flag-leaf stage), and may require a longer wilt time than some forage types. Fychan et al. (2007) determined that a 48-hour wilt time for perennial ryegrass resulted in the most optimum DM level, as well as reduced mold cover at feeding. McCormick (2006) listed average wilting times for various forages, including 48 hours for annual ryegrass, four hours for bermudagrass and bahiagrass, 24 hours for crabgrass, 48 hours for sorghum, and 24 hours for alfalfa.

Once forages are wilted to achieve proper moisture levels, baling and wrapping should occur immediately. Baleage production requires the purchase or contract use of a bale wrapper to prepare bales for ensiling and storage following baling. Wrappers are categorized as single-bale or in-line. Within the single-bale category, there are platform, swinging-arm, and bale-spear types. Platform and swinging arm wrappers are opposite in their mechanisms. Platform wrappers hold the roll of plastic steady while the bale is moved to facilitate wrapping. Swinging-arm wrappers hold the bale in one place while an arm holding the roll of plastic moves around the bale to wrap it. The bale-spear type rotates the bale on a spear while the plastic is being applied (Sears et al., N.D.). In-line wrappers wrap bales in a tube-like fashion and are popular because they decrease the amount of plastic used and can wrap bales faster than individual bale counterparts do. Shinnars et al. (2008) found that there was a significant reduction in plastic use

when using an in-line wrapper compared to wrapping bales individually (4.5 g plastic/kg DM vs. 9.3 g plastic/kg DM, respectively). They also found that the in-line wrapper took significantly less time to wrap each bale than the individual wrapper (46 seconds and 92 seconds, respectively).

Bales should be wrapped tightly to exclude as much oxygen as possible. Excessive oxygen content can decrease the efficiency of the ensiling process, which may result in dry matter loss and nutritive value loss. Increased oxygen availability in the bale can also lead to excessive heating, causing decreased digestibility (Jones et al., 2004). Wrapping bales with white polyethylene plastic film is preferred to help exclude oxygen from the bales and keep heat absorption minimized during storage. Six layers of plastic should be applied, stretched 50-75% and overlapping by 50%. Studies (McCormick, 1998; Muck, 2006) have shown that four layers of plastic can be acceptable, although six is recommended for extra protection from tears in the plastic, as well as for forages that might have been baled at a moisture that is not considered optimum (McCormick, 2008).

Baleage needs to be stored six to eight weeks before feeding to ensure that the ensiling process is completed and can be stored up to 12 months before feeding to ensure maximum nutritive value (Sears et al., N.D.). High-quality forage provides the framework for success during the ensiling and fermentation process. Fermentation of baleage begins with a moisture range of 40-60%, sufficient WSC levels, and oxygen exclusion from the bale. When the baleage is wrapped in six to seven layers of stretched plastic, oxygen is excluded. Plant respiration consumes the remaining oxygen sealed in the bale (Muck, 2006). Anaerobic bacteria, mainly lactic acid bacteria, convert sugars (soluble carbohydrates) to lactic acid, ethanol, and acetic acid. While the lactic acid bacteria accounts for a small percentage of total bacteria present on the

plant, the anaerobic environment, coupled with the lactic acid bacteria's competitive nature, allows it to quickly reproduce and become one of the main bacteria present. High-quality forages provide soluble carbohydrates needed to begin the fermentation process. Dewhurst et al. (2003) reported that annual ryegrass baleage harvested at the boot and early dough stages had a soluble carbohydrate level of 21.4% upon harvest. In this study, they compared annual ryegrass to alfalfa, red clover, and white clover for baleage production. These other forages had water-soluble carbohydrate levels of 6.4, 10.0, and 8.4%, respectively. WSC were established by taking samples of each forage at harvest and testing prior to ensiling, illustrating the amount of readily soluble substrate for acid producing bacteria in annual ryegrass compared to other forages. McCormick et al. (2008) found that brown midrib (BMR) sorghum had a WSC value of 13.72% when ensiled and sorghum x sudangrass had a value of 7.61% on a dry matter basis, which demonstrates that summer annual grasses may provide sufficient fermentation substrates for use in a baleage production system. According to Woolford and Palhow (1997), as these soluble carbohydrates are used, there is an increase in acid production, which causes a drop in pH in the bale to the point where a subsequent fermentation known as clostridial fermentation is prevented. Clostridial fermentation occurs when lactic acid, carbohydrates, and proteins present in the forage are converted to butyric acid and ammonia by clostridial bacteria. These products are associated with spoilage and a decline in the quality of the fermented forage (Muck, 2006). Baleage with relatively higher pH values are more likely to grow mold. While no current research shows this mold having negative effects on the animal, it may influence intake and palatability of the stored forage product. Oxygen presence increases mold growth, which illustrates the importance of proper wrapping and handling of bales, as well as ensuring that any

punctures in the plastic are covered with an appropriate tape immediately. Acetic acid levels are also important when considering mold growth, as it inhibits mold and yeast (Muck, 2006).

Feeding and Animal Performance

Improved animal performance may occur with baleage systems when forage quality is superior to that of hay or silage. The potential for increased performance is largely driven by the ability of the producer to harvest forage at a higher quality stage of growth than with more traditional systems, and improved intake.

Charmley and Firth (2004) performed a 98-day feeding trial comparing feeding growing beef cattle flail-chopped, precision-chopped, and round bale timothy silage stored on pavement outdoors for five months in year one and seven months in year two before feeding. The flail-chopped silage was not wilted and had a DM concentration of 16.9% at harvest. The precision-chopped silage had a DM concentration of 47.7%, and round-bale silage had a DM concentration of 58.5%. The animals in this study gained 1.00 kg/day with the flail-cut silage and 1.61 kg/day with the round bale silage in year one. In year two, they gained 0.68 kg/day, 1.04 kg/day, and 0.76 kg/day with the precision chopped. A higher DM intake was seen for the round-bale treatments (8.9 kg/day) over the flail-chopped (6.8 kg/day).

Hancock (2010) found baleage to have total dry matter losses of 10 to 25% when compared to hay stored under a roof (15-35%) or stored on the ground and uncovered (30-60%). This total loss value includes losses from harvesting and baling, storage, and feeding. It was also shown in this study that ryegrass baleage resulted in a higher average daily gain than bermudagrass hay or ryegrass hay with values of 0.88 kg/hd/d, 0.71 kg/hd/d, and 0.56 kg/hd/d.

Martin et al. (2014) performed a pre-conditioning study at LSU that compared bermudagrass hay, ryegrass and rye baleage at either early boot or late bloom stage of maturity, and bermudagrass baleage. Two-hundred and forty calves were fed for 60 days, resulting in average daily gains that were greatest for full bloom stage ryegrass and rye baleage (0.58 kg/d) and lowest for bermudagrass hay and bermudagrass baleage (0.37 kg/d and 0.32 kg/d, respectively), with the early boot stage ryegrass and rye baleage being intermediate at 0.46 kg/d. They concluded that feeding baleage in a pre-conditioning system resulted in animal performance that was superior to that of hay, which may be related to improved intake of baleage compared to hay.

Palatability of baleage may initially be an issue for calves. However, this can usually be overcome with an adequate adjustment period at the beginning of feeding. McCormick et al. (1998) demonstrated no difference in intake among annual ryegrass baleage (7.8 kg DM/d) and hay (7.8 kg DM/d) after a ten day acclimation period to ryegrass haylage, as well as no differences in total weight gain among treatments with an increase of 10.9 kg for baleage and 16.8 kg for hay. This lack of difference in intake between baleage and hay has been demonstrated with alfalfa (Evans et al., 1982) as well as bermudagrass (Berthe et al., 1991), following an adequate adjustment period.

Annual Ryegrass for Baleage Production

Annual ryegrass is a common forage grown in the Southeast that is often used for feeding livestock, through grazing, hay, or baleage. It is considered ideal for ruminants in the Southeast during the cool season months because of its uniform growth pattern, sward stability under grazing, and favorable agronomic characteristics (Lippke and Ellis, 1997). Over one million

hectares of ryegrass are grown in the US every year, with 80% of that being in the Southeast (McCormick et al., 2014). Ryegrass yields 6,725 to 15,692 kg DM/ha, depending upon the planting date and method used for establishment. When utilized as baleage, annual ryegrass can offer an advantage over hay production systems in that there are reduced losses due to rainfall on drying hay and leaching of nutrients (Martin et al., 2011). This reduced drying time also enables the forage to be cut in the boot stage, at a higher moisture and nutritive value. Areas of the Southeast have high annual rainfalls, such as Alabama with 142 centimeters/year (NOAA, 2017). This rainfall is usually highest in the months of March through July, which coincides with the time frame that most forage is cut for hay. Annual ryegrass has a unique advantage with its reduced drying time, which McCormick (2012) reported may reliably provide harvested forage two to four weeks earlier than in a hay production setting.

While annual ryegrass is in a vegetative state, dry matter digestibility levels are usually over 70% and crude protein may exceed 20% on a DM basis (Lippke and Ellis, 1997), illustrating the high quality of this forage. In a study by Grigsby et al. (1998), hand-plucked samples were taken from three different ryegrass pastures in three different areas of Texas (Angleton, Overton, and Knippa) in mid-January. NDF values were 37.51, 32.08, and 39.92%, ADF values were 21.75, 16.58, and 21.71%, and crude protein values were 22.80, 32.14, and 31.17% on a dry matter basis for each location, respectively. These data demonstrate that initial quality of annual ryegrass during vegetative growth may exceed the nutrient needs of most classes of livestock early in the season. As the growing season progresses, yield potential increases and quality decreases slightly. On average, annual ryegrass cut in the vegetative-boot stage will have a CP value of 12 to 16% DM, ADF value of 27 to 33% DM, NDF value of 47 to 53% DM, and TDN value of 63 to 68% DM. When cut in the boot-head stage, there will be a CP value of 8 to 12%

DM, ADF value of 33 to 39% DM, NDF value of 53 to 59% DM, and TDN value of 59 to 63% DM (Ball et al., 2015). These stages of growth provide adequate yield of dry matter per acre and mid-to-high quality forage when harvested for baleage or hay production. McCormick et al. (1998) found that ryegrass stored as baleage or haylage maintained a higher crude protein value (19.8 and 19.2 % DM, respectively) than hay (13.1% DM) when harvested within two weeks of one another during mid-April in Louisiana. The authors also noted that there was no difference between storage losses in annual ryegrass stored as baleage when compared to hay stored in a barn, illustrating that a baleage production system may be a feasible way to preserve forage DM for a time of later use.

Supplementation Strategies for Stored Forages in Pre-conditioning Systems

When designing a supplementation strategy, the first thing that must be taken into account is the quality of the forage being used. Whatever forage is being fed must be analyzed for nutritive value. Beyond this consideration, the nutrient requirements for the animal must be considered, as well as the production goals for the system. For example, the NRC (2016) requirements for a 250 kg steer show a net energy for maintenance (NEm) of 4.8 Mcal/d, plus 3.8 Mcal/d of net energy for growth (NEg) to gain 1.2 kg/d, whereas an 800 kg steer has an NEm of 13.3 Mcal/d plus an NEg of 6.4 Mcal/d for the same gain. This is a total difference of 11.1 Mcal/d of net energy, so these animals would require different supplementation strategies when fed the same forage. The needs of the animal must be matched with what the forage is providing and any discrepancies will have to be accounted for in the supplementation strategy. In other words, if the forage is not sufficient in crude protein for the class of animal being fed, a protein supplement is needed, or if

it is deficient in energy, energy supplements will be utilized to ensure the animals are receiving the nutrition they need.

Cost is often the deciding factor in the selection of a supplement. In the Southeast, there are several cropping systems that produce byproducts suitable for supplementing beef cattle. The cotton industry provides gin trash, cottonseed hulls, cottonseed meal, as well as whole cottonseed, which are generally used to correct protein deficiencies in the diet with crude protein values as high as 44.98 % DM for cottonseed meal (NRC, 2016). The distilling industry produces dried distillers grains and there are other industry byproducts such as peanut hulls, soy hulls, bakery waste, citrus pulp, and corn gluten feed. These byproducts are often used in commercial and on-farm feed blends to provide a feed supplement ranging from 12 to 16% CP and 60 to 75% TDN depending on the type of livestock to be fed and their stage of production. There are multiple computer software options for balancing rations and establishing supplementation strategies, which can help producers develop least-cost supplementation approaches.

When using annual ryegrass baleage in the Southeast for a pre-conditioning system, energy is expected to be more limiting than protein for cows and growing calves. This results in a need for high energy supplements such as dried distillers grains plus solubles (TDN 89.0% DM), corn gluten feed (TDN 80.0% DM), soybean hulls (TDN 62.6% DM), or whole corn (TDN 84.6% DM) (NRC, 2016).

Economics of Baleage Systems

When considering making baleage for a beef operation, most producers' first question and concern would be the cost. There are costs associated with baleage that go above and beyond just

making hay or grazing beef cattle on pasture. While the raw numbers can be intimidating, the potential economic advantage for baleage is most seen in improved forage utilization and nutritive value (Pruitt and Lacy, 2013). Pruitt and Lacy (2013) also mention that less dry matter losses may be seen in baleage over hay, which may result in an economic advantage, as well as possible reductions in supplementation costs due to the higher crude protein and TDN values of some baleage. In this economic analysis, it was established that it would take 36 feeding days for a herd of 200 head of cattle to break even on the purchase of an in-line wrapper with an estimated 60 cents of savings per head from improved forage quality plus savings from reduced dry matter storage loss. For a herd of 500 head, this dropped to 14 cents. They also found that the total costs per ton, on an as-fed basis, for a conventional hay baler would be \$8.63, \$10.04 for an in-line wrapper and high-moisture baler, and \$13.81 for an individual wrapper and high-moisture baler. The authors conclude that it would be cost-effective for cow-calf producers with 150 head or more to purchase a bale wrapper and high-moisture baler over traditional hay-making practices.

Hersom et al. (2007) noted differences baling Tifton-85 bermudagrass as hay or baleage on the same 20 hectare field. One half of this field was managed to produce only hay, while the other was managed for hay and baleage. The hay-only section was cut as weather and growth conditions permitted. The hay/baleage section was cut on four-week intervals and baled as hay when drying conditions allowed, and wrapped for baleage when they did not. They found that more cuttings were possible when using the complimentary system, which resulted in a higher number of bales produced. Mean bale CP and TDN were higher for the complimentary system, as well. They concluded that utilizing a system where the forage could be preserved as hay or

baleage based on weather conditions resulted in more conserved forage that was higher in quality than the hay-only system.

If a producer is not interested in purchasing a high moisture baler and wrapper of their own, there are other options for making baleage. Contract baling and wrapping is an option, as well as purchasing baleage pre-made. The advantage to these options is the elimination of the cost of purchasing the equipment necessary to wrap bales. However, the price for contract baling and wrapping can be high enough that money may be lost, ultimately, and borrowed equipment might not be available when the forage needs to be cut and wrapped.

II. PRE-CONDITIONING BEEF CALVES WITH HIGH-MOISTURE STORED FORAGES AND CO-PRODUCT FEEDS

INTRODUCTION

Pre-conditioning systems are used to add weight to weaned calves. The pre-conditioning phase usually lasts from 30 to 60 days and is ideal for preparing calves to enter a stocker or feedlot operation by training them to eat out of a feed bunk and use a waterer, as well as offering an advantageous time period for dehorning, castration, and providing vaccinations. For a stocker producer or cow/calf producer, it can also be a way to add value to calves prior to marketing. In the southeastern United States, cattle in a pre-conditioning program are usually grazed on pasture or fed hay, silage, or baleage, and fed supplement as needed to achieve gain. Supplements might include dried distillers grains, whole cottonseed, soybean hulls, citrus pulp, or corn and are typically byproducts of other regionally-based cropping systems. In recent years, there has been a renewed interest in using high-moisture stored forages, such as silage or baleage as part of cattle production systems within this region.

Baleage is a term for harvested forage that has been baled, wrapped, and ensiled at 40 to 60% moisture. It is considered a good option for the Southeast because the waiting period associated with drying hay is reduced, which may help forage be harvested at a higher level of quality due to less influence of weather conditions on the system. Cool season annual grasses and legumes are ideal candidates for making baleage because of their crude protein, total digestible nutrients, and moisture content. Annual ryegrass is one of the most commonly used forage species in this system among producers. However, there have been limited studies evaluating the expected animal performance and economics of this system in comparison to more traditional approaches of feeding a corn-silage or by-product based ration for backgrounding calves. A 45-

day pre-conditioning evaluation was conducted at the EV Smith Research Center in Shorter, Alabama to test the hypothesis that animals fed baleage during this period would outperform animals fed corn silage or bermudagrass hay. Specific objectives were to evaluate animal performance, diet quality, and economics of these feeding options for growing beef calves.

MATERIALS AND METHODS

Research Site

A 45-day pre-conditioning study was conducted at the E.V. Smith Research Center in Shorter, Alabama to evaluate the use of annual ryegrass baleage in a pre-conditioning system for growing beef calves when compared to bermudagrass hay and corn silage. All procedures were previously reviewed and approved by the Auburn University Institutional Animal Care and Use Committee (Protocol Number 2015-2710).

For the evaluation, 54 weaned Simmental-Angus heifers and 54 weaned Simmental-Angus steers were sorted by sex and assigned randomly to one of three diets. Each pen contained 12 animals, six heifers and six steers. Total pen space in each pen was 286 m² with a 72 m² covered loafing area and inline feed bunks 6.7 meters in length.

Forage Harvest

Annual ryegrass was harvested in the boot stage from a six hectare field on the research station on April 22, 2015 after having been fertilized according to recommendations from the Auburn University Soil Testing Laboratory. On April 23, 2015, ryegrass from four hectares of a six hectare pasture were baled and wrapped and an additional two hectare pasture was harvested when forage had achieved a moisture level of 40 to 60%. Forage moisture estimates were

conducted using the microwave test method (Steevens et al., 1993). The remaining ryegrass was baled and wrapped on April 24, 2015. Corn was harvested and chopped in the milk stage on July 13, 2015 and stored in polyethylene silo storage bags. Tifton 85 bermudagrass used for the study was fertilized according to Auburn University Soil Testing Laboratory recommendations on April 28, 2015. Bermudagrass hay used for the study was harvested on a 4-wk frequency from May through July 2015.

Animal and Feed Management

One-hundred and eight weaned beef calves were used for the evaluation. Calves were weighed initially [initial body weight (BW) 279 ± 34.7 kg], sorted by sex, and assigned randomly to one of three treatments. Nine feeding pens were used for the study with three pens per treatment. Twelve calves were allocated per pen (six heifers and six steers) to allow for 0.45 m of bunk space per calf. Treatments consisted of three pre-conditioning diets (% DM basis): 1) 67% annual ryegrass baleage plus 33% of a 50:50 mixture of soybean hulls and corn gluten feed, 2) 69% Tifton 85 bermudagrass hay plus 31% of a 50:50 mixture of soybean hulls and corn gluten feed, and 3) 84% corn silage plus 4% corn and 12% cottonseed meal. Supplemental feeds were selected to reflect commonly purchased feed sources by cattle producers in the Southeast. Diets were formulated to achieve a target gain of $0.7 \text{ kg hd}^{-1} \text{ d}^{-1}$ based on the NRC (2000) requirement for a 270-kg growing calf. Treatment diets were formulated to be isocaloric. Thirty percent waste was added to the dry matter intake requirements listed in the NRC (2000) to ensure cattle achieved ad libitum intake of individual diets. Calves were placed in pens on d -5 to allow for acclimation to the diet. Amount fed per day of each diet was: 1) 18 kg/head/day of annual ryegrass with 4 kg/head/day of the 50:50 mixture, 2) 9 kg/head/day of Tifton 85 bermudagrass

hay with 4 kg/head/day of the 50:50 mixture, or 3) 24 kg/head/day of corn silage with 0.5 kg/head/day of corn and 1.4 kg/head/day of cottonseed meal, on an as-fed basis. Feed was weighed in and out of bunks on a daily basis throughout the duration of the feeding trial. Cattle had access to water and mineral *ad libitum* for all treatments during the evaluation.

Animals were weighed on d 0, d 21, and d 44. Average daily gain (ADG) was calculated per animal by subtracting the weight on Day 0 from the midpoint weight and the final weight, divided by the total number of days on treatment. Initial BW, final BW, and ADG are reported in Table 1.

Laboratory Analysis

Initial samples were taken of baleage and silage after fermentation and hay after drying and scanned using a near infrared spectrophotometer (NIR) to obtain initial quality data for use in formulating diets. Concentrations of acid detergent fiber (ADF), neutral detergent fiber (NDF), crude protein (CP), and total digestible nutrients (TDN) were estimated using prediction equations developed by the NIRS Forage and Feed Testing Consortium (Hillsboro, WI). 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 bulked and used for laboratory analyses. Baleage and silage samples were frozen immediately at the research station. Samples were collected weekly and transported to the Auburn University Ruminant Nutrition Laboratory.

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, Sweddsboro, NJ) before nutritive value analysis. These

samples were compiled by week and analyzed for ADF and NDF values (Van Soest et al., 1991) using an ANKOM 2000 Automated Fiber Analyzer (ANKOM Technology, Macedon, NY) and CP values by finding the concentration of N according to the Kjeldahl procedure (AOAC, 1995) using a FOSS Kjeltac 8200 (FOSS, Eden Prairie, MN). CP was then determined as $N \times 6.25$. TDN was calculated using ADF values. The equation for TDN of annual ryegrass baleage and bermudagrass hay was $98.625 - (1.048 * ADF)$. The equation for TDN of corn silage was $82.14 - (0.577 * ADF)$ (SGS Agrifood).

An *in vitro* fermentation trial was conducted with each forage type and diet used in the feeding study. Treatments for the *in vitro* study included ryegrass, bermudagrass, or corn silage alone compared to ryegrass baleage + 50:50 soy hulls and corn gluten feed, bermudagrass hay + 50:50 soy hulls and corn gluten feed, or corn silage + 85:15 corn and cottonseed meal. Initial sample weight per incubation flask was 0.75 g (forage plus supplement). The amount of supplement added to each incubation jar was estimated based on a 272-kg growing steer consuming 2.5% of their body weight per day in dry matter with a target ADG of 0.7 kg/d. Rumen fluid was collected at 4:00 pm at the Auburn University College of Veterinary Medicine from a cannulated Holstein cow that was offered *ad libitum* access to bermudagrass hay and a supplement feed was 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. The rumen fluid was then transported to Upchurch Hall in pre-warmed thermos containers where it was strained to remove any particulates. 0.75g of sample plus 16.5mL of rumen fluid and 33mL of phosphate-carbonate buffer (pH 6.8) were placed in 75-mL flasks (Fisher Scientific, Pittsburgh, PA) and fitted with a rubber stopper before being placed in a 39°C water bath incubator (ThermoFisher Scientific, Waltham, MA).

Each treatment was run in duplicate over seven time points (0, 3, 6, 12, 18, 24, 48) following inoculation. As samples were removed from the water bath, the flasks were placed in the refrigerator to stop fermentation prior to filtration through Whatman filter paper. Residues were placed in a 100°C oven to dry overnight, then stored prior to NDF analysis. 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* dry matter digestibility and NDF digestibility.

Economic Analysis

An economic analysis was conducted to establish the relative cost of each treatment. The reported market data from the Alabama Weekly Hay Report and Alabama Weekly Feedstuff Report (USDA AMS, 2015) 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. Calves were sold in a commercial sale at the Montgomery Stockyards, LLC (Montgomery, AL) on November 2, 2015, November 3, 2015 and December 1, 2015.

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-day backgrounding study. Diet was considered a fixed effect. The PDIF 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. Regression analysis was performed

with *in vitro* digestibility data to evaluate changes in fermentation metrics over the incubation times up to 48 hours.

RESULTS AND DISCUSSION

Animal Performance

There were no differences in initial (283.8 ± 3.2 kg) or final (314.5 ± 3.4 kg) body weight of beef calves fed high-moisture or hay-based diets during the feeding evaluation. Following the 45-day feeding evaluation, no differences ($P = 0.3327$) were observed in the average daily gain (ADG) of calves fed annual ryegrass baleage, corn silage, or bermudagrass hay-based rations (Table 1). Gain per day was between 0.61 and 0.73 kg/d for calves consuming the diets evaluated. While ADG of calves fed baleage-based diets was numerically lower than that of the silage and hay rations, all calves fed these diets gained close to the NRC (2000) expected gain of 0.7 kg/d. When comparing early boot stage rye and ryegrass baleage to late bloom stage rye and ryegrass baleage, bermudagrass baleage, and bermudagrass hay, Martin et al. (2014) experienced ADGs lower than those observed in the present study at 0.46 kg/d for 60 days. The authors reported that boot stage rye and ryegrass baleage had a CP value of 12.8% and a TDN value of 64.5% on a DM basis. However, Hancock (2010) found that animals fed annual ryegrass baleage have a greater ADG than those fed bermudagrass hay or ryegrass hay at 0.88 kg/d. The author reported a CP of 16.3% DM, and a TDN of 65.9% DM for ryegrass baleage used in the evaluation. The values observed in the present study were intermediate to those reported by these

other recent evaluations. Based on these trials, it appears that annual ryegrass baleage animal performance can vary, but values similar to or greater than those of hay-based diets are commonly observed. The quality of the baleage used in these studies differed, which suggests that high quality annual ryegrass baleage can lead to gains seen in the trial by Hancock (2010). Keady (2005) compared nine studies in Ireland with growing beef calves fed corn silage diets and observed that inclusion of corn silage in the diets of beef cattle could increase dry matter intake by 1.5 kg DM/d and resulted in an ADG of 1.02 kg/d. In a 121 d trial, Young and Kauffman (1978) observed an ADG for animals fed a corn silage-based diet of 1.09 kg/d. Martin (2014) observed gains of 0.37 kg/d for cattle fed bermudagrass hay plus a liquid supplement for 60 days. Vagnoni et al. (1995) compared Alicia bermudagrass hay supplemented with corn and cottonseed meal compared to ammoniated bermudagrass hay with or without monensin and urea supplementation for growing beef calves. The authors observed daily gains of 1.05 kg over 98 days for the bermudagrass hay treatment. This bermudagrass hay had a higher CP value (12.8%) than this study, but otherwise was similar in quality to the other forages. Coffey et al. (2002) performed a 3-year study providing ad libitum access to bermudagrass hay supplemented with grain sorghum for growing stocker calves. The authors reported an ADG of 0.71 kg/d across the three years. These data are similar to those observed in the present study when moderate quality bermudagrass hay was fed. In this study, baleage did not provide an advantage over the silage or hay-based diets. If annual ryegrass had been harvested sooner, an increase in quality may have been observed, which would have allowed for more potential for improved animal performance.

Table 1. Animal performance of growing beef calves fed various forage diets during a 45-d pre-conditioning trial.

	Treatment ¹			SE
	RB	CS	BH	
Animals, n	36	36	36	
Initial body weight, kg	287	282	282	3.1
Final body weight, kg	314	315	314	2.9
Average daily gain, kg/d	0.61	0.72	0.73	0.075

¹RB = 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-week frequency from May through June 2015.

Nutritive Value

Table 2 shows the nutritive value of each of the forages used in the pre-conditioning diets in this study. Differences were observed in CP, NDF, ADF, and TDN % among forage types ($P < 0.10$). Crude protein values of annual ryegrass baleage and bermudagrass hay were greater than corn silage. This observation fits with expected values for corn silage, which range from 7.8 to 9.3% CP (Bal, 2006 and Martin, 2008). Concentration of NDF and ADF was greater for bermudagrass hay and ryegrass baleage than corn silage. Lesser values for ADF in corn silage led to an increased TDN percentage for this forage type compared to ryegrass baleage and bermudagrass hay (70.6% vs. 62.0 and 61.3%, respectively).

The bermudagrass CP value of 9.9% DM seen in this study is consistent with past studies. Mandebvu et al. (1998) compared Tifton 85 bermudagrass hay harvested at 3.5 weeks and 7 weeks. The CP values they observed were 15.5 % DM at 3.5 weeks and 9.0 % DM at 7 weeks. The NDF value seen by Mandebvu et al. (1998) was higher at 79.3 and 83.0% DM than the value of 67.0% DM seen in this study, illustrating there was less accumulation of indigestible cell wall components in the bermudagrass hay fed in the 45-day evaluation. They also compared both bermudagrass harvest frequencies to corn silage. Concentration of CP for corn silage in

their trial was 9.3% DM, which is higher than what was seen in this 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 trials. However, NDF values were lower in this study when compared to Mandebvu et al. (1998) at 38.0% vs. 51.0% DM, respectively. Overall, the hay and silage used in this study were mostly similar in quality with past research conducted in the southeastern US. McCormick et al. (1998) harvested annual ryegrass for baleage in the boot stage, and observed greater CP values than were seen in this study (19.8 vs. 10.0% DM), which demonstrates that the baleage quality in this study was lower than what was expected. Concentration of NDF values, however were very similar, with a value of 56.2% DM seen by McCormick, compared to 56.5% DM in this study. The values reported for all forage types used in this feeding evaluation illustrate mid-quality forage. Beef producers often target daily gains at 0.7 to 0.9 kg (1.5 to 2.0 lbs) in pre-conditioning systems. 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 (NRC requirements are 7.8 kg/d DMI, 56.6% TDN, 8.7% CP).

In vitro dry matter digestibility (IVDMD) of forage diets (Figure 1) differed across digestion time points ($P=0.0069$), and showed an increase in diet digestibility increased over time. The greatest digestibility occurred at the 48-h time point with an average value across treatments of 71.6 % DM. This value is similar to the estimated TDN calculated in the analysis of bulk samples collected from each harvested forage type. Digestibility increased from three to 12 h from 41.2% to 59.6% ($P = 0.0224$). From 12 to 48 h, there were no differences in digestibility, although there was a numerical increase in digestibility from 59.9% to 71.6%. The 48-h digestibility time point is most commonly used to report IVDMD in forage evaluations. These differences were expected, as microbial activity increases over the course of 48 h, more

digestion is expected to occur. The 48-h digestibility of 71.6% is consistent with IVDMD found by McCormick et al. (1998) for annual ryegrass hay (71.1%). Martin et al. (2008) observed an IVDMD of 67.0% for corn silage, which was also consistent with the results in this study. Overall, the IVDMDs of these forages were relatively high. Digestibility of each forage type and diet combination used in the feeding evaluation were compared at 3, 6, 12, 24 and 48-h during the digestion process. There were no differences in IVDMD among forage diet treatments ($P = 0.1519$; Figure 2) at the various time points during the digestion trial. The diets were expected to be similar in nutritive value, as all three were formulated to meet the needs of a growing beef steer gaining 0.7 kg/d. Supplementation of forage diets did not increase IVDMD compared to forage alone in the digestion trial.

Table 2. Forage nutritive value of various forage diets fed to growing beef calves during a 45-d pre-conditioning trial.

	Treatment ¹			SE
	RB	CS	BH	
DM, % as fed	40.79	38.04	85.23	
Nutrient Analysis ²				
CP	10.0 ^a	6.9 ^c	9.9 ^b	0.35
NDF	56.5 ^a	38.0 ^b	67.0 ^a	2.78
ADF	34.9 ^a	19.9 ^b	35.6 ^a	2.28
TDN	62.0 ^b	70.6 ^a	61.3 ^b	5.01

¹RB = 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-week frequency from May through June 2015

²Values reported on a % DM basis

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

Figure 1. *In vitro* dry matter digestibility of forage-based diets for pre-conditioning growing beef calves over time ($P=0.0069$).

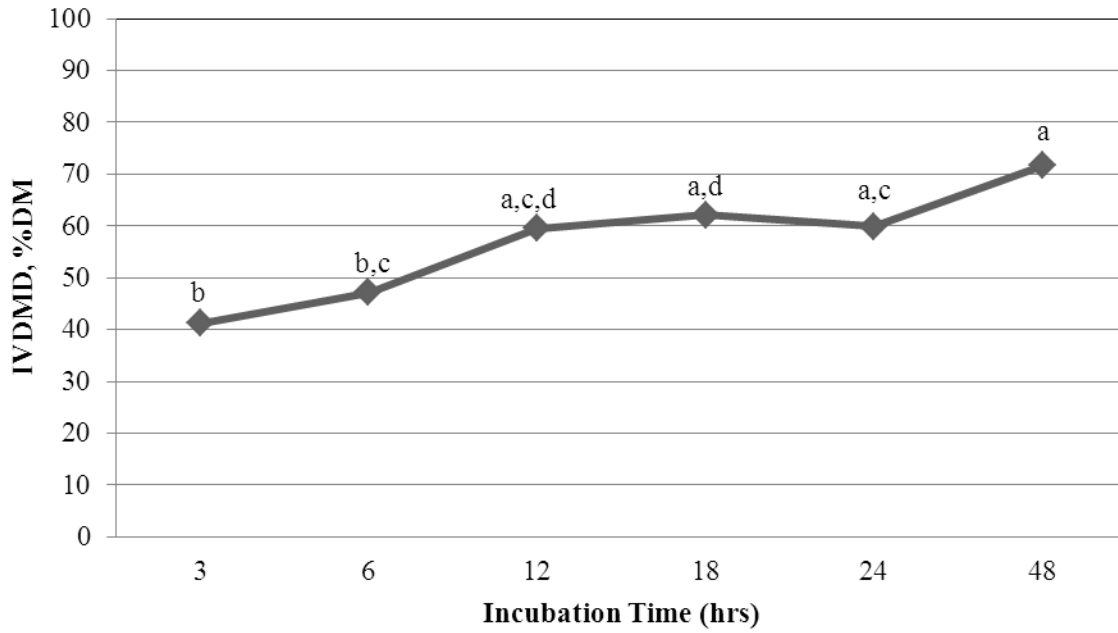
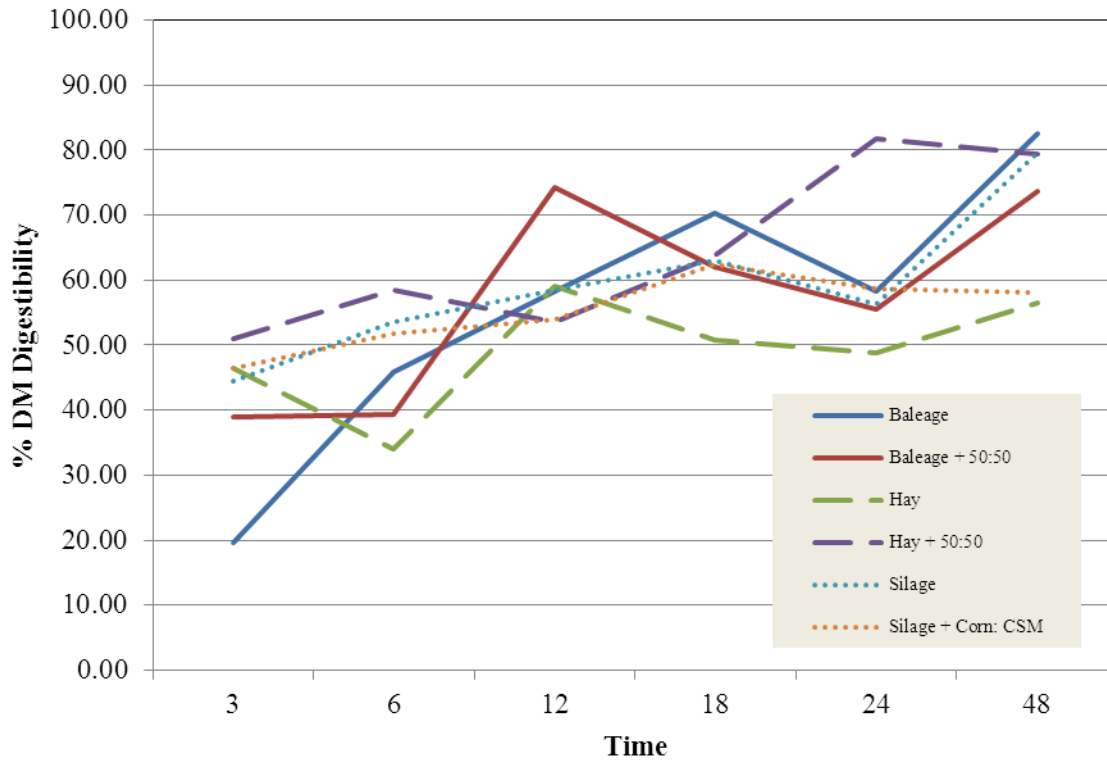


Figure 2. Treatment effects ($P=0.1519$) on *in vitro* dry matter digestibility of various stored forage diets for pre-conditioning growing beef calves over 48 hours.



Economics

Table 3 shows the diet costs for annual ryegrass baleage, corn silage, and bermudagrass hay. Baleage was shown to be more expensive on a per head basis than hay, at \$1.37/hd/d vs. \$0.95/hd/d. Silage was intermediate at \$1.02/hd/d. This diet cost was similar to that found by Pruitt and Lacy (2013) and reported data from Hersom et al. (2007). They found a diet cost for baleage of \$1.26/hd/d in a split bermudagrass hay/baleage system. These authors also analyzed the economics of purchasing a baleage wrapper. One of their conclusions was that the ultimate cost savings associated with feeding baleage is a result of reduced losses in harvest, storage, and feeding. However, a beef operation must be large enough in order to justify the cost and make purchasing the equipment worthwhile. According to the authors' calculations, a herd of 125 head would require 87 feeding days of baleage a year to break even on the purchase of an in-line bale wrapper. 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 head. Calf prices received at sale barns in the Southeast reached an all-time high in 2014 and 2015 (USDA, 2017). Since that time, feeder calf prices have declined and moderated. Producers considering methods to add value to calves at the time of sale may consider pre-conditioning if the cost of gain is less than the value of gain.

Table 3. Economics of stored forage-based diets for growing beef calves pre-conditioned for 45 d.

	Treatment ¹		
	RB	CS	BH
Diet Cost, \$/head/d	1.37	1.02	0.95

¹RB = 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-week frequency from May through June 2015

SUMMARY AND CONCLUSIONS

Results of this study suggest that diets containing annual ryegrass baleage, when supplemented, can support gains in pre-conditioning systems similar to those containing Tifton 85 bermudagrass hay or corn silage. However, baleage did not support improved gains over the other two forage-based diets in this particular study. This is because the baleage had similar forage quality to that of the bermudagrass hay and corn silage. In order for baleage to have a competitive advantage over these established systems, there must be improved dry matter preservation, quality, and as animal performance observed. An economic analysis of this study showed that the cost of baleage systems was greater than hay or corn-silage based diets for growing beef calves. Producers considering the use of baleage should compare the costs of their current production system to the potential additional considerations needed to make high-quality baleage. For some, the addition of baleage to their current system could be beneficial to their overall operation as a way to take advantage of more frequent cuttings or utilization of hay that would otherwise lose quality before harvest and baling. Producers also have access to tools such as the Baleage Decision tool (Pruitt and Lacy, 2014), which is offered in the form of a Microsoft Excel spreadsheet. This tool allows producers or extension professionals to input specific variables, such as the size of the herd, weight of hay or baleage bales, yield per ton, input costs, and storage losses. The spreadsheet then calculates costs per hour and per bale for baling baleage (in-line and individual) and baling hay, as well as forage production costs per acre, ton, bale, and cow. This can give producers an idea of whether baleage fits into their system from a financial sense.

Future research in this area may focus on agronomic management of baleage for improved dry matter preservation and quality. Harvest frequency and preservation techniques, such as the

use of fermentation enhancers, may influence quality at the time of storage and feeding. Animal performance evaluations should assess differences in intake and forage waste in these systems to determine where costs can potentially be reduced further.

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