Evaluation of Warm-Season Baleage in a Cow-Calf Production System

by

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ABSTRACT

A 52-d feeding trial was conducted to compare pearl millet (PM) and sorghum × sudan (SS) harvested as baleage with bermudagrass hay (B) fed to cow/calf pairs during a winter feeding system. Alternating cone (C) and open-shaped (O) rings were evaluated for minimizing forage wastage. A total of 12, two hectare, pastures populated with three cow/calf pairs per pasture were utilized in this study. Each pasture had a different forage × ring treatment, including: PM × C, PM × O, SS × C, SS × O, B × C, and B × O; with a replicate of each forage × ring treatment. Forage quality parameters were measured for each treatment and included ash, CP, IVTD, NDF, ADF, and ADL. Animal performance was also recorded including initial and final cow BW and BCS, initial and final calf BW, and cow milk production at day 32 and 52 of the feeding trial. Differences ($P < 0.10$) were observed among forage for concentrations of ash, CP, NDF, ADF, ADL and percentage IVTD. Forage ash concentration and percentage IVTD were greater ($P > 0.10$) in PM and SS baleage than bermudagrass hay, whereas the CP, NDF, ADF, and ADL concentrations were less ($P > 0.10$) than bermudagrass hay. There were no ($P > 0.10$) forage × ring interactions or differences between open and cone-shaped hay ring treatments for forage waste; however, the percentage of waste from PM and SS baleage was greater ($P < 0.10$) than that of bermudagrass hay. There were no forage × ring interactions ($P > 0.10$) for cow initial BW, final BW, initial BCS, or final BCS. There were no differences ($P > 0.10$) in cow weight or BCS loss among forage treatments or ring shape in this study. There were also no forage × ring interactions, or differences among forage or between ring-shape treatments ($P > 0.10$) for milk production and calf BW gain. Calf weight gain differed ($P < 0.10$) between ring-type treatments, with calves on the open-shaped ring treatment weighing 6.13 kg more than calves on the cone-shaped ring treatment. Because there were no differences ($P > 0.10$) in animal performance, this study suggests it would not be economical to harvest forage as baleage to supplement lactating beef cows during a fall-winter forage gap. Harvesting forage as baleage might be economical for a producer with cattle having higher CP and IVTD requirements, such as growing steers or lactating dairy cows; as well as, a herd size greater than the one utilized in this study. Results of this study suggest purchasing a cone-shaped hay ring is not an advantageous business decision because the percent of forage waste and animal performance did not differ ($P > 0.10$) between the cone and open-shaped hay rings.

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I. LITERATURE REVIEW

Baleage

Baleage is harvested at high moisture levels, allowed to wilt to 50 to 60% moisture, and then wrapped in plastic wrap so that it will ferment. Anaerobic microorganisms ferment some of the soluble carbohydrates in the forage to lactic acid, which inhibits the growth of detrimental microorganisms. This process will consume some DM and DE, but the loss is small compared with DM losses that result from the harvesting of hay (Sears et al., 2013). Baleage should be wrapped in 4 to 6 layers of stretch film to exclude any oxygen and allowed to ferment for a minimum of 30 days, but 60 days is preferred prior to feeding (McCormick et al., 1998). Unlike hay or silage, baleage will only remain stable for 8 to 12 months and should be fed no later than a year after wrapping (Lemus, 2010). The forage crop should be cut at earlier maturity stages to ensure high sugar content, which is essential for proper fermentation. Legumes should be cut at 10% bloom, and grasses at the boot stage or just as the head emerges. Crops such as oats, rye, triticale, and barley should be cut before the boot stage (Sears et al., 2013).

Baling at proper moisture content is critical for producing quality baleage. If baled below 40% moisture, fermentation can be restricted and mold production can ensue. If baled at about 65% moisture, the producer runs the risk of reducing forage quality, increasing the chance of undesirable butyric acid fermentation, and reducing the amount of DM stored per storage unit. Because forages are harvested at higher moisture content, the curing time can be decreased, which reduces the risk of rained-on hay, especially in the spring and summer seasons when rain can be unpredictable. Fewer leaves are lost because of decreased raking, so baleage will typically have greater CP and TDN concentrations, resulting in higher quality forage when compared with dry hay. Hersom et al. (2007) compared bermudagrass harvested as hay and baleage from the same field, and authors recorded improved CP (12.9%) and TDN (57.1%) for forage harvested as baleage compared with hay (10.1% CP and 53.8% TDN).

The disadvantages of a baleage system are the increased cost per bale due to machinery and cost of plastic wrap, plastic wrap disposal, limited transportation due to cost and weight of the bales, and spoilage risk if the bag becomes punctured. Wrapping bales can also slow the baling process and/or increase labor needs (Andrae et al., 2005). Baleage should address a time in which supplemental nutrient demands are needed in a herd, to fill the fall-winter gap or the spring-summer gap. It is a valuable resource in reducing or eliminating the amount of grain fed to an animal to meet daily nutrient requirements.

Baleage species

One of the most important variables in producing good-quality forage is plant species. When choosing a forage species, factors such as region, climate, and type of production system being used need to be taken into consideration. Cool-season plants, or C3 plants, are adapted to cooler climates with an optimum temperature range of 18 to 24°C (Betts, 2016). Theses grasses and legumes are more productive during the spring and fall seasons because of shorter photoperiods and higher soil moisture. Warm-season plants, or C4 plants, are better adapted to warmer climates and grow best at 32 to 35°C

(Betts, 2016). Compared with C3 plants, C4 plants are generally lower in CP, but animals use the protein more efficiently. The C3 plants are often higher quality than C4 plants because they degrade faster in the rumen due to thinner cell walls and leaf tissues, whereas C4 plants usually produce a higher yield (Betts, 2016). In a study completed by Pruitt et al. (2013), when winter annuals were properly harvested, nutritional requirements of lactating beef cows or growing steers and heifers could be met satisfactorily. Bermudagrass harvested as baleage may not meet nutritional requirements of a lactating cow or growing animal, and the animals would need additional supplementation. The real economic benefit of baleage lies in the ability to harvest high-quality forages such as winter annuals, summer annuals, or legume crops such as alfalfa. Legumes do not contain high amounts of water-soluble carbohydrates (WSC) because the concentration of simple sugars and fructan levels are low, making these forages difficult to ensile. Because legumes have a greater CP percentage than grasses, the fermentation process during ensiling is restricted due to the increased concentration of ammonia and its buffering capacity. Small grains and ryegrass are easily ensiled because of their high WSC levels. Bermudagrass is difficult to ensile because of its low sugar concentration, high buffering capacity, and fermentation of some substrates (malic and oxaloacetic acids) to weak acids (acetic) that buffer near pH = 5 (Lemus, 2010).

Wastage

Baleage is utilized largely because of its dependability to reduce waste at feeding. Because it is highly palatable and high quality, cattle usually consume more baleage DM than from hay, which leads to increased intake and profit for the producer. It also typically results in DM storage losses of only 5 to 10% compared with as much as 30% in hay that is stored outside with no cover (Lane, 2009). Due to deterioration and weather exposure, large round bales stored outside may have as much as 25% or more of the bale wasted at the feeder, whereas baleage results in 10% or less waste (Gunn, 2014). Refusal rates by cows can also be a huge factor loss. Refusal rates of dry hay can add another 10 to 20% to hay losses. Not only is baleage effective for reducing waste at feeding, it is also reduced when harvesting. Every extra day of delayed baling amounts to a 6% yield loss on the following cutting. Therefore, waiting five days to bale hay (which is very typical in the summer months) can mean as much as 30% yield reduction (McCormick, 2011).

Pearl millet

Pearl millet (*Pennisetum americanum*) originated in Africa, is a warm-season annual forage that has potential to produce high-quality and quantity feed during spring and summer months. This forage is better adapted to acidic soils and soils with lower water-holding capacity than sorghum × sudangrass hybrids. One benefit of pearl millet is its drought tolerance compared with other forages because it has an extensive root system. A pH of 5.5 to 6.5 is required for maximum production. Fertilizer recommendations should be based on soil test, but if one is not available, 78 to 101 kg/ha of P_2O_5 and K_2O is recommended prior to seeding, and 67 to 90 kg/ha of actual N should be applied at seeding and 45 to 67 kg/ha after each cutting or intensive grazing (Teutsch, 2009). The soil temperature should reach at least 18°C before planting because of the forage's sensitivity to cold stress. In the Southeast, the soil will reach this temperature around May or June. The optimum temperature for growth is 33 to 35°C with a minimum of 12°C (Newman et al., 2010). When planted during May or June and fertilized with N, yield may range from 5,604 to 11,209 kg/ha. Total yield decreases as seeding date is delayed from earliest planting. Newman et al. (2010) reported that delaying planting until July resulted in losses as high as 20%. Millet that is planted in the spring should be ready for grazing 30 to 40 days after planting and should be productive for 80 to 110 days, with the majority of the productivity seen in the first 60 days. Seed can be broadcast at a rate of 28 to 45 kg/ha onto a fine but firm seedbed, and then cultipacked to ensure good soil-seed contact. If seeding using a grain drill, it is recommended to reduce seeding rate to 17 to 22 kg/ha. The seeding depth should be between 1.27 and 2.54 cm (Teutsch, 2009). Seeding rates at the higher end of the recommended ranges could promote higher leaf: stem ratio, which would improve forage quality, but these gains may not compensate for the expense of the higher seeding rate. Pearl millet produces several stems from a central plant; therefore, it requires 15 to 20 cm of stubble to regrow following grazing or harvesting as hay or silage. Grazing should begin when plants reach 51 to 61 cm in height, but regrowth rate and animal performance are optimized if a 23-to 30-cm stubble height is maintained. The forage should be cut for hay when the plant reaches 61 to 91 cm tall, also known as the boot stage or early head stage (Hancock, 2009). One advantage of pearl millet is its rapid growth that provides grazing in as little as 45 to 60 days. If harvested prior to maturity, the range of TDN can be 52 to 58%, whereas CP will range from 8 to 11% (Hancock, 2009). This forage is high in calcium and iron and has balanced essential amino acids, but sulfur-containing amino acid concentration is low (Newman et al., 2010). There is no concern with prussic acid poisoning because it does not produce hydrocyanic acid, so cattle can graze at any point in the growing season. There is however, a concern about nitrate poisoning when heavy N fertilization is followed by drought, trampling, and cloud cover. Nitrates are taken up by the plant but not utilized because plant growth is restricted by the drought. Nitrate levels above 0.9% can be lethal and milk production can be reduced if nitrate concentration exceeds 0.6% of DM (Newman et al, 2010). In cattle, nitrate is converted to nitrite in the rumen and then absorbed in the blood stream. Nitrite interferes with the blood's ability to carry oxygen and can result in trembling, rapid pulse, followed by coma and death. To avoid nitrate poisoning, excessive amounts of N fertilizer should not be applied and drought-stressed or slow-growing plants should not be grazed (Teutsch, 2009). If irrigation is used or there is adequate rainfall, nitrate poisoning is not common. The ensiling process of baleage and silage can reduce nitrates by 40 to 60%.

Tifleaf 3

Tifleaf 3 is a pearl millet variety that is a hybrid between Tift 85DA, Tift 83, and Tift 383. It is a semi-dwarf, leafy forage hybrid that shows more resistance to rust (*Puccinia substriata)* than Tifleaf 2 at an immature growth stage and showed good resistance to leaf spot (*Piricularia grisea*), the major diseases on pearl millet forages in the USA (Hanna et al., 2005). This hybrid matures later than most tall hybrids and supplies grazing for longer periods in the summer. Tifleaf 3 and Tifleaf 2 are similar in DM yield, forage quality, and IVDMD. There is a difference in DM yields when there is a moderate disease infection before the middle of August or as planting dates are delayed later in the season. Both of these scenarios usually result in higher DM yields for Tifleaf 3 (Hanna et al., 2005). Yields of commercial Tifleaf 3 seed can usually be doubled by producing hybrid seed Tif8593, a F1 cytoplasmic-nuclear male sterile, instead of inbred Tif85DA. Increasing seed yields of this product will keep seed prices reasonable and at the same time provide a high-quality summer forage (Hanna et al., 2005). Phosphorus and potassium requirements for Tifleaf 3 can usually be met by applying 113 kg of 0-10-20 for every 45 kg of N applied. Fertilization will increase yield, and heavy fertilization will also increase protein and vitamin A (Hanna et al., 2005).

Sorghum × sudangrass

Another warm-season forage of African origin, sorghum × sudangrass (*Sorghum bicolor*) has very similar characteristics to pearl millet. Sorghum × sudangrass is a hybrid between forage sorghum and sudangrass, and it has the potential to be the highest yielding summer annual in the Southeast if adequate rainfall is received or irrigation is provided. This forage species is more severely affected by drought than pearl millet, and less tolerant of poor soil conditions and soil pH values less than 5.8 (Hancock, 2009). These hybrids are best adapted to well-drained, fertile soils, but will grow on imperfectly drained soils when surface water is removed (Teutsch, 2009). Ideal soil pH is 6.5 but should be between 6 and 7.5, and soil temperature at 5 to 10 cm should be 18 to 21° C. A study conducted by Fontaneli et al. (2001) compared pearl millet and sorghum × sudangrass cultivars across six seeding dates and measured yield, yield distribution, and nutritive value. Across all cultivars, forage DM yield decreased linearly at a rate of 25 to 30 $\text{kg} \bullet \text{ha}^{-1} \bullet \text{d}^{-1}$ for each day seeding was delayed. The authors attributed the lower yield of later seedings to summer droughts, cool fall temperatures, and shorter days. The recommended seeding depth is 1.9 to 4.4 cm in heavy soils and up to 5 cm in sands (Undersander, 2001). Seed can be broadcast at a rate of 34 to 45 kg/ha onto a fine but firm seedbed, or 22 to 34 kg/ha if seeding with a grain drill. Because of the potential for prussic acid poisoning, it is recommended that sorghum × sudangrass not be grazed or cut for green-chop until the plant is 61 to 76 cm tall. Young, drought-stressed, or frosted forage presents increased risk for prussic acid poisoning (Teutsch, 2009). Cutting sorghum × sudangrass for hay or silage is difficult due to coarse stems, but can be alleviated by mower-conditioners. The forage should be cut at the late-boot to early-head stage for hay or wilted silage. Sorghum × sudangrass is expected to yield 4,483 to 11,209 kg/ha of hay; 26,900 to 33,626 kg 35% DM silage per hectare; or can be grazed 45 to 60 days after planting (Teutsch, 2009). At this stage, sorghum × sudangrass will typically have TDN values in excess of 53 to 60% and CP concentrations of 9 to 15%. If grazing this forage, brown midrib (BMR) varieties are preferred because they have less lignin and greater digestibility than other varieties. BMR varieties could improve animal gains as much as 5 to 8% compared with non-BMR varieties (Hancock, 2009).

Alta seed 6402

Alta seed 6402 is a late-maturing sorghum × sudangrass variety that has brachytic dwarf characteristic and provides high leaf-to-stem ratio. This variety is known for superior standability and excellent re-growth, as well as superb tonnage under multiple harvest systems (Alta Seed, 2015). Its reduced internode length creates a compact, leafy, and prolific plant without sacrificing yield compared with taller sorghum× sudan hybrids. Alta seed 6402 should be harvested at 40 days or 260 cm of growth; delayed harvest allows for seed heads to develop and will result in decreased protein and increased energy concentration due to continued sugar formation in the stalks and leaves, and carbohydrate deposition in the developing grain. Ten centimeters of stubble is critical for re-growth to ensure two nodes are remaining (Alta Seed, 2015). In studies performed by Alta Seed, AS6402 had 34.95% ADF; 11.17% CP; 17,618 kg/ha yield; 71.49% IVTD at 30 hours; and 57.41% NDF. These values may be compared with two other varieties, NC+44S and DK SX17, whose %ADF were 41.20 and 42.66; %CP 6.70 and 7.20; DM yield (kg/ha) 19,187; %IVTD at 30 hours 62.63 and 60.2; and %NDF 62.18 and 65.91, respectively. Alta seed 6402 also has the BMR-6 trait that decreases lignin concentration and produces a more palatable and digestible forage. In a study reported by Porter et al. (1978), sorghum plants with the genotype BMR-6 performed better than sorghum plants without BMR-6. In a two-year study, % lignin was lower and % IVDMD was greater for sorghum plants with the BMR-6 genotype in both years of study (Porter et al., 1978). One side effect of the BMR trait is a greater percent of lodging, but the use of the brachytic height gene in this species of sorghum × sudan is a mechanism that addresses the lodging issue. This gene primarily inhibits internode elongation until after floral initiation, which tends to create short internodes that give more stability (Morgan and Finlayson, 2000).

Bermudagrass

This warm-season perennial grass native to southeast Africa has gained popularity in the southeast United States because it is productive during the months of June, July, and August when the quantity and quality of cool-season grasses are poor. It is deep-rooted, sod-forming grass that spreads by means of stolons and rhizomes and grows to a height of 38 to 61 cm (Hansen et al., 2000). Herbage production of bermudagrass (*Cynodon dactylon*) is distributed more evenly throughout late spring and summer than that of other warm-season grasses, allowing it to be grazed or harvested for hay when soil moisture is not limiting. Its extensive root system provides some drought tolerance, and it is adapted to a wide range of soil conditions, but is best suited to a well-drained site. It can be grown on shallow, droughty soils, but it does not tolerate waterlogged conditions. Like most grasses, it does best at a pH of 5.5 or above and is highly responsive to the application of N fertilizer (Hansen et al., 2000). Bermudagrass is a high-yielding grass; 11,209 to 15,692 kg/ha can be produced with good management and ample moisture. In the South region of the U.S., beef cattle farms depend on bermudagrass as primarily grazed forage from early spring until autumn. Bermudagrass hay is fed to cattle during winter, transition periods of seasonal deficiencies in available forage, and drought periods. Stands often persist and remain productive for more than 35 years and withstand a variety of environmental conditions such as acidic sandy soils, moderate to heavy grazing pressure, variable rainfall, and differing management (Scaglia et al., 2012). Because hybrid varieties produce little or no viable seed, they must be vegetatively propagated; also known as sprigged. Sprigged and seeded varieties are available, but sprigged varieties generally have a yield advantage over seeded varieties. Fresh sprigs should be planted at 34 to 45 kg/ha at 5 to 8 cm depth. Using the press wheels on the sprigging machine or the tractor wheels after planting will help ensure good soil contact and enhance soil moisture retention during dry weather (Lee et al., 2013). Seeded varieties can either be broadcast or drilled into a well-tilled, level and firm seedbed at a depth of 0.64 cm and 4.5 to 9 kg of pure live seed per hectare (Hansen et al., 2000). Grazing can begin when the forage is 15 to 20 cm tall, and cattle should be taken off pasture when the forage is 8 to 10 cm to ensure proper regrowth. Bermudagrass varieties that produce rhizomes can be planted from late January until late July. Early sprigging (before the grass breaks dormancy) allows for more favorable soil moisture conditions that provide sprigs a higher level of stored food reserves to initiate growth once temperatures are warm enough for growth to occur. Sprigs dug in early spring, just after the plants have broken dormancy, will have lower levels of food reserves (Lee et al., 2013). Bermudagrass that is well fertilized, harvested at the proper time, and stored to minimize losses can produce high yields of good quality hay. Harvesting at 4-to 5-week intervals represents the best compromise between forage yields and quality, allowing a high proportion of leaves to stems and ease in curing. In good hay-drying conditions, the moisture content should be low enough for baling (less than 20%) in 24 to 36 hours (Lee et al., 2013).

Tifton 85

Tifton 85 is one of the highest yielding and highest quality F1 hybrids between PI 290884 from South Africa and Tifton 68 bermudagrass (Burton et al., 1993). Compared with other hybrids, this forage is taller, has longer stems and broader leaves, and is darker green in color. Hay yields and digestibility are considerably better than Coastal, Tifton 44 and Tifton 78 hybrids. Its large rhizome and stolons spread rapidly and may grow 5 to 7 cm a day; however, it is not as cold tolerant as Coastal and is best adapted to the Coastal Plain region (Lee et al., 2013). The potential as a high-quality hay and pasture forage is based upon its rapid growth rate and high IVDMD values. A study conducted by Hill et al. (1993) compared Tifton 85 with Tifton 78 bermudagrass pastures in terms of forage quality and grazing steer performance. Coastal and Tifton 44 bermudagrass were included as baseline forages to represent currently recommended cultivars. Tifton 85 produced 26% greater DM yield with 11% greater IVDMD than Coastal in two 3-year yield trials. Analyses comparing Tifton 85 with Tifton 78 revealed greater CP concentration for Tifton 85 in September, whereas May and July values were similar; IVDMD was greater in May and September for Tifton 85; mean and medium particle size were greater for Tifton 85 in May, July, and September samples; grazing days/hectare were greater for Tifton 85 and, consequently BW gain/hectare was 46% greater for Tifton 85 than for Tifton 78 (Hill et al., 1993).

Animal performance

Cattle production in the southeastern U.S. compromise mainly cow-calf operations from which 70% of all calves produced in the region are sold at weaning (McBride and Mathews, 2011). Cow-calf operations dominate in the Southeast because the climate and forage availability make this type of beef cattle operation more ideal.

McBride and Mathews (2011) classified cow-calf producers as “residual users” of land, which is limiting or fragmenting cattle operations into smaller operations due to the opportunity cost associated with crop production or recreational activities. The majority of cow-calf operations in the Southeast are small in number of head maintained and the number of acres managed. McBride and Mathews (2011) reported that the U.S. Southeast had an average of 59 head per farm and operated only 183 hectares per farm using data from the 2008 Agricultural Resource Management Survey (ARMS). Feed costs in the cow-calf sector are often greater than 60% of total production costs, with a large portion of those cost from forage expenditures. Thus, evaluating harvested forge management practices and, adopting new schemes that may increase forage quality, as well as reduce DM losses and feed wastage, are essential to minimizing wintering feed costs and maintaining profitability (Gunn, 2014).

Profitability in the cow-calf business is influence by the percentage of cows in the herd that consistently calve every 12 months. Cows that fail to calve or take longer than 12 months to produce and wean a calf increase the cost per pound of calf produced by the herd. Most reproductive failures in the beef female can be attributed to improper nutrition and thin body condition. The condition of cows at calving is associated with length of post-partum interval, subsequent lactation performance, health and vigor of the newborn calf, and the incidence of calving difficulties in extremely fat heifers (Herd et al., 1998). The condition of cows at breeding affects their reproductive performance in terms of services for conception, calving interval, and the percentage of open cows. Body condition scores (BCS) are numbers used to suggest the relative fatness or body composition of the cow. The scoring system is based on a 1-9 range, with 1 to 4 reflecting thin conditions, 5 to 7 reflecting moderate conditions, and 8 to 9 reflecting fat conditions. The acceptable body condition score prior to calving is at least 5, or possibly 6. A BCS = 5 cow will have 0.38 to 0.61 cm of fat cover over the 13th rib, approximately 14 to 18% total empty body fat, and about 3.75 kg of weight per cm of height (Herd et al., 1998). A BCS higher than 6 may or may not be detrimental, and scores at calving of less than 5 will impede reproduction.

Physiological status and cow performance

Ensuring proper nutrition for the beef cow not only affects her body condition, but also promotes proper growth and development of the growing fetus (NRC, 2016). Early postpartum is the period of greatest nutritional demand. The cow must lactate, repair their reproductive tracts, resume heat cycles, breed, increase activity, and grow (Hall et al., 2009). Therefore, supplemental energy may be required to maintain body weight and condition of cows when forage alone does not meet animal demands. Prepartum and postpartum energy balance are the most important factors affecting duration of the postpartum interval to first estrus in beef cows (Hess et al., 2005). Therefore, feeding programs should be designed to keep cows in positive energy balance maintaining moderate body condition. Cows that are thin at calving usually have longer postpartum intervals compared with cows in good body condition at calving that can tolerate minimal body weight changes before and after calving (Corah et al., 1974).

Cow size, milk production, pregnancy, activity, and environment are the primary influences on nutrient needs of cattle (NRC, 2016). The TDN and CP requirements during the last third of pregnancy are about 20 and 14% greater than during the middle third of pregnancy, respectively. For example, a mature cow weighing 544 kg requires 47.4% TDN and 6.6% CP during gestation. The same cow's nutrient requirements increase to 54.6% TDN and 8.6% CP between 60 to 90 days before calving (Hall et al., 2009).

The nutrient requirements of the animal need to be reconciled with the quality of forage to determine if any supplemental feed needs to be added to the diet. Cow protein and energy requirements are greater during lactation than any other time of the 12-month production cycle, and the requirement increases with increasing milk production (Adams et al., 1996). In a study conducted by McCormick et al. (1998), lactating Holstein cows were fed ryegrass harvested as baleage and as hay. Cows consuming both types of forage had similar forage intake, but cows fed hay had an increased grain intake of 1.5 kg of DM that resulted in an increased total intake of 18.4 kg DM for cows consuming hay compared with 17.0 DM for cows consuming baleage. Cows consuming baleage produced an average of 27.4 kg of fat-corrected milk (FCM, 3.5%) wheras cows consuming hay only produced an average of 22.8 kg of FCM (3.5%). Because of a greater total intake and lower milk production, cows consuming hay had a lower feed efficiency of 1.43 whereas cows consuming baleage had a feed efficiency of 1.61. The greater nutritive value of baleage resulted in diets containing less grain than required for hay diets, which led to improvements in the conversion of DM to milk (McCormick et al., 1998). In a later study by McCormick et al. (2011), the lactation performance of mid-lactating Holstein cows was measured when fed baleage (BAL), outdoor-stored hay (OSH), and barn-stored hay (BSH). Conservation method had little effect on post-storage CP levels, but ADF and NDF concentrations were greater in OSH than in either BSH or BAL, which resulted in a 12.8% depression in net energy for OSH compared with other treatments. Concentrate DMI in kg/d was similar across treatments, whereas forage DMI was similar for OSH and BSH, and similar for OSH and BAL. Bahiagrass conserved as OSH showed greater DM losses, resulting in lower nutritive value and a tendency for lower DMI and milk yield than BSH. Storage losses, nutritive value, and lactation performance were similar for BSH and BAL; therefore, baleage conservation system may substitute for indoor-store hay systems without expectation of increased storage losses or declines in animal performance.

Weigh-suckle-weigh

Milk production is the primary factor controlling weaning weight of beef calves, and there is an increased interest in the relationships between the level of milk production, calf performance, dam's body condition and the reproductive performance of the postpartum, lactating beef cow. The weigh-suckle-weigh (WSW) method is a practical way to indirectly measure milk production in beef cattle, and is obtained by taking the difference in calf weight before and after suckling following an interval of separation of the calf from the cow (Knapp and Black, 1941; Drewry et al., 1959; Dawson et al., 1960; Kress and Anderson, 1974). Reported intervals of separation of the

WSW technique ranged from 4 hr (Dawson et al., 1960) to 16 to 19 hr (Kress and Anderson, 1974). Williams et al. (1979) performed a study utilizing the WSW method to measure milk production in Hereford cows with three separation intervals of 4, 8, or 16 hours to determine their effect on estimates of milk production. The 8-hr separation interval gave the best estimate of milk production during early lactation because it 1) had less measurement error and higher correlation with calf average daily gain than the 4-hr interval; and 2) produced less observable irritation and discomfort in the cows and was closer to the natural interval than the 16-hr interval. Milk production can be influenced by the quality and quantity of feed available. Brito et al. (2008) conducted a study with late-lactating dairy cows fed alfalfa baleage cut at sundown (PM) and then cut at sunrise (AM) on the following day. Baleage cut at sundown had greater concentrations of total nonstructural carbohydrates (TNC), and digestible organic matter intake, organic matter digestibility, and plasma Lys concentration were significantly greater in cows fed PM alfalfa, suggesting that more nutrients were available for milk synthesis. The authors observed significant lower body weight gain and retained N as a proportion of N intake in cows fed PM alfalfa, but this was attributed to nutrients being channeled to milk synthesis rather than to body reserves. They concluded that intake of DM (19.9 vs. 19.0 kg/d), and yields of milk (20.1 vs. 19.2 kg/d), milk fat (0.82 vs. 0.74 kg/d), and milk protein (0.64 vs. 0.60 kg/d) were significantly greater in cows fed PM vs. AM alfalfa, and that the increase in milk yield and composition would most likely increase calf ADG and weaning weights.

Economics

Because pasture, feed and forage costs constitute two-thirds of the operating expenses in a beef cow-calf operation, there has been considerable interest from beef cattle producers in using baleage as a way to reduce feeding expenses (Pruitt et al., 2013). The initial purchase of a high-moisture baler and wrapper must be incurred in order to harvest baleage. If a conventional baler is currently being used in an operation, some manufactures sell kits that will convert balers to be able to handle hay that has higher moisture content. These kits are available for $300 to $1,000, but may not be available from every manufacturer or for all balers (Pruitt et al., 2013). The purchase price of a conventional round baler is typically $31,500 compared with $36,500 for a high-moisture round baler (Pruitt et al., 2013). High-moisture balers are recommended because they have scrapers on the belts and rollers to prevent buildup of material, and they have heavy-duty bearings to help handle the increase in bale weight (Sears et al., 2013). There are two major ways to store forage as baleage: utilizing an individual bale wrapper or an in-line wrapper that continuously wraps bales. The individual bale wrapper generally costs less and runs on hydraulics of the tractor towing the wrapper, but it does not wrap bales as quickly (3 to 6 minutes per bale), requires more labor and uses more plastic (20 to 25 bales per roll of plastic). In contrast, the in-line wrapper costs significantly more, runs on its own gasoline-powered engine, wraps bales substantially quicker, and uses less plastic (30 to 40 bales per roll of plastic). The average purchase price of the individual wrapper is typically $22,500 compared with $30,000 for the in-line wrapper, but individual wrapping machines are difficult to find due to lack of popularity. The in-line wrapper may initially be more expensive to purchase, but it has advantages with lower operating, plastic and labor cost, resulting in the total wrapping and harvesting costs for an individual wrapper of $13.81 per ton on an as-fed basis, compared with $10.03 per ton on an as-fed basis for the in-line wrapper (Pruitt et al., 2013).

Hay vs. Baleage

The cost associated with the harvesting of hay and baleage, expressed as total cost per ton (as-fed basis), using a conventional hay baler is $8.63, compared with $10.04 when using a high-moisture baler and in-line wrapper, and $13.81 when using a high-moisture baler and individual wrapper (Pruitt et al., 2013). Hay that is harvested and stored without protection from environmental elements can result in 25% or more of the crop's DM being lost prior to being fed, while DM loss for plastic wrapped bales typically is about 5%. Assuming a hay field produces 10,088 kg of hay (DM basis) per hectare over three cuttings and a cow consumes 1,633 kg of hay (DM basis) during a 150-day winter-feeding period, the cost per cow is $280 assuming 25% hay loss. When the hay loss prior to feeding is only 5% for bales wrapped in plastic, the total cost per cow are $233.04 and $245.11 for the in-line and individual wrapper, respectively. Cost savings are then $46.96 per cow for the in-line wrapping system and $34.89 per cow for the individual wrapping system compared with costs for the conventional round baler (Pruitt et al., 2013).

Data from a single year study conducted at the University of Florida was analyzed in the University of Georgia Basic Balancer to estimate dollars per feeding day for bermudagrass hay and baleage. Increased tonnage of DM per hectare (10.01 vs. 15.44), CP% (10.1 vs. 12.9), TDN% (53.8 vs. 57.1), and decreased kg of supplemental grain (3.08 vs. 1.68) for hay compared with baleage resulted in a ration cost in dollars per day of $1.86 for cows consuming hay compared with $1.26 for cows consuming baleage (Hersom et al., 2007). No allowance was made for storage and feeding losses, concluding that producers would spend $0.60 per day less to feed a cow using baleage as opposed to hay.

A simple pole barn can be constructed for roughly a third to half of the combined cost of a bale wrapping machine and high-moisture round baler. McCormick et al. (2011) showed storage losses in % DM were 12.8, 2.9, and 0.3 for hay stored outdoors, hay stored in a barn, and wrapped as baleage, respectively. The use of a barn to store hay will decrease storage losses, but this requires that the hay is dry to prevent mold and/or fires. Producers cannot always cut, harvest and store hay when it is dry. Therefore, the cost of a hay barn and additional supplementation can exceed the costs of owning and operating a bale wrapper (Pruitt et al., 2013).

Break-Even Herd Size

The results from Hersom et al. (2007) and the UGA Basic Balancer are interpreted to mean that cow-calf operations with less than 100 cows will find it difficult to justify purchasing an in-line baleage wrapper, whereas producers with herds larger than 150 cows should strongly consider purchasing an in-line baleage wrapper because it takes only a few feeding days to recoup the additional operating costs and amortized payments. This break-even herd size is based on decreased storage and feeding losses and does not take into account lower feeding cost. When the combination of lower feeding costs and reduced storage losses are taken into account, producers with herd sizes as small as 75 cows rationally can consider purchasing an in-line bale wrapper, on the basis of improved forage quality and reduced storage and feeding losses, since a relatively short feeding period of 95 days will pay for additional operational and ownership costs of the bale wrapper (Pruitt et al., 2013). The high per-hour cost of operation may make it cost-prohibitive for small cattle operations to purchase a high-moisture baler and bale wrapper, but use in a custom wrapping situation can bring down the hourly costs and help the additional machinery pay for itself. Some custom operators wrap baleage, and many local entities (County Extension, conservation districts, cattlemen's groups, etc.) may have wrappers available for rent to diminish the ownership cost (Sears et al., 2013). In general, producers with cow-calf operations that have at least 150 cows in the herd will find the decision to purchase a bale wrapper and high-moisture baler to be cost-effective compared with employing conventional hay-making systems. Producers with cow-calf operations of less than 100 cows are less likely to find such a purchase to be economical, unless they use the machinery in a custom hire enterprise.

Plastic disposal

The plastic used to store baleage prevents oxygen from infiltrating the forage and allows fermentation to occur. Plastics have replaced longer lasting and/or natural materials that have commonly been used such as concrete silos and sisal twine. Plastic is safer to use, improves production efficiency, cost less, and permits more flexibility in management compared with other packaging. Unfortunately, the plastic used for making baleage can only be used once and disposal is a potential environmental issue. Most agriculture plastic is disposed of at landfills but some is left in the fields, plowed into the ground, or burned in an open fire. Currently, there are no standard policies for collection and disposal of used baleage plastic beyond landfill disposal (Sears et al., 2013). Efforts to recycle used plastic have been implemented in areas that have enough plastic to warrant the collection and recycling of other agricultural plastics. Cornell University has developed a Recycling Ag Plastics Project (RAPP) to promote farmer adoption of best management practices to keep agriculture plastics in condition to be recycled, acquire mobile baling equipment to compact used plastic for cost-efficient transport from farms to recyclers, and cultivate manufacturing markets to process used plastic into new products. This program is still in an experimental phase, but further research will reduce environmental and cost concerns regarding disposal of plastic used to store high-moisture forages.

II. EVALUTION OF WARM-SEASON ANNUAL BALEAGE IN A COW-CALF PRODUCTION SYSTEM

INTRODUCTION

Baling forages at higher moisture levels than what is required for dry hay offers many advantages. Usually, excessive spring or summer rainfall makes it nearly impossible to dry down forages into the 15 to 18% moisture range, which is necessary for hay production in the Southeast. As a result, warm-season forages are often mature when baled as dry hay (Sears et al., 2013). Harvesting forage as baleage, which requires a higher moisture range (40 to 60%) and shorter field-drying time, can produce forage with greater CP and TDN concentrations, resulting in a higher quality forage than dry hay (Hersom et al., 2007).

Because it is highly palatable and high quality, cattle usually consume more DM conserved as baleage than hay, which leads to increased intake and profit for the producer. It also typically results in DM storage losses of only 5 to 10% compared with as much as 30% in hay that is stored outside with no cover (Lane, 2009). Because this production system is less weather-dependent, curing time is reduced, and more nutrients are preserved in the forage rather than leaching into the soil due to weathering events. Every extra day of delayed baling amounts to a 6% DM yield loss on the following cutting. Therefore, waiting 5 days to bale hay (which is very typical in the summer months) can mean as much as 30% yield reduction (McCormick et al., 2011).

Harvesting warm-season forages as baleage can produce a stored feed for the fall-winter forage gap. Warm-season forages, or C4 plants, are generally lower in CP than cool-season forages, or C3 plants. Typically C3 plants are of higher quality than C4 plants because they degrade faster in the rumen due to thinner cell walls and leaf tissues, whereas C4 plants usually produce a greater DM yield (Betts, 2016).

Because of their high yields and adequate forage quality, warm-season annual forages are a good forage to harvest as baleage and then utilize as a stored forage during various forage gaps. Pearl millet (*Pennisetum americanum*) originated in Africa and is a warm-season annual forage that has potential to produce high-quality and quantity feed during spring and summer months. This forage can produce 5,604 to 11,209 kg DM/hectare when planted during May or June and fertilized with N (Newman et al., 2010). Tifleaf 3 is a pearl millet variety that is a hybrid between Tift 85DA, Tift 83, and Tift 383. It is a semi-dwarf, leafy forage hybrid that has greater resistance to rust (*Puccinia substriata)* than Tifleaf 2 at an immature growth stage, and has good resistance to leaf spot (*Piricularia grisea*), which is the major disease on pearl millet forages in the USA (Hanna et al., 2005).

Another forage of African origin, sorghum × sudangrass (*Sorghum bicolor*), is a warm-season forage that has very similar characteristics to pearl millet, and it has the potential to be the highest yielding summer annual in the Southeast U.S. if adequate rainfall or irrigation is provided (Hancock, 2009). This forage is expected to yield 4,483 to 11,209 kg DM/hectare and have TDN values in excess of 53 to 60% and CP concentrations of 9 to 15% (Hancock, 2009). Alta seed 6402 is a late-maturing sorghum-sudangrass variety that has brachytic dwarf characteristic and provides high leaf-to-stem ratio. This variety is known for superior standability and excellent re-growth, as well as superb tonnage yield under multiple harvest systems. Alta seed 6402 also has the BMR-6 trait that decreases lignin concentration and produces a more palatable and digestible forage. Compared with non-BMR varieties, BMR varieties could improve animal gains as much as 5 to 8% (Hancock, 2009).

Because pasture, feed, and forage costs constitute two-thirds of the operating expenses in a beef cow-calf operation, there has been considerable interest among beef cattle producers in using baleage as a means to reduce feeding expenses (Pruitt et al., 2013). Utilizing warm-season annuals harvested as baleage to supplement cow-calf pairs during the winter may reduce feed cost for producers tremendously. The majority of research to date has involved cool-season forages harvested as baleage. Because baleage typically has a relatively short storage period of 8 to 12 months, harvesting warm-season forages is much more practical to supplement cow-calf pairs during the winter. With decreasing calf prices and increased feed cost, the cow-calf producer is compelled to find a feasible method to maintain cow BW and increase calf weight during the winter months. For this reason, a 52-day feeding trial was conducted to compare forage quality and waste of pearl millet and sorghum x sudan baleage with bermudagrass hay, for fall-calving lactating cows as assessed by weigh change and milk production during the winter months.

MATERIALS AND METHODS

Research Site

On June 6, 2016, 2.4 hectares of “Tifleaf 3” pearl millet were planted for the experiment, as well as an additional 2.4 hectares of “AS6402” sorghum × sudangrass. The pastures were located within a field at the E.V. Smith Research Center (EVSRC) in Shorter, AL (32.3668 °N, 86.3 °W) that had been used for soybean production prior to the initiation of the experiment. The soil type is primarily a Marvyn sandy loam, 0 to 2% slope, whereas the southwest corner of the sorghum × sudan pasture is a Bama fine sandy loam, 0 to 2% slope. Temperature and precipitation data were collected from the Alabama mesonet weather station at EVSRC. All procedures were approved by the Auburn University Institutional Animal Care and Use Committee for the use of live vertebrate animals in experiments (PRN 2014-2438).

Forage management

“Tifleaf 3” pearl millet and “AS6402” sorghum × sudan were planted at a seeding rate of 17 kg/ha and 22 kg/ha, respectively. Both pastures received 15 cm of irrigation using a pivot following planting and 392 kg/ha of 17-17-17 N-P_2O_5-K_2O was applied. On June 15, August 6, and September 1, 2016, the pearl millet and sorghum × sudan pastures were fertilized with 67 kg N/ha with liquid 28-0-0-5 utilizing a Hagie sprayer. To prevent fall armyworms and prevent the occurrence of the sugar cane aphid from reducing forage mass, carbaryl Sevin® XLR (Tessenderlo Kerley, Inc. Phoenix, AZ) was applied to both pastures at a rate of 1.40 kg/ha on July 6, 2016. To further control the spread of armyworms, methoxyfenozide Intrepid® 2F (Dow AgroSciences LLC, Indianapolis, IN) was applied to both pastures on July 22, 2016 at a rate of 0.42 kg/ha. Pastures were sprayed for the third time to kill remaining armyworms on August 19, 2016 with lambda-cyhalothrin Karate with Zeon Technology® (Syngenta Crop Protection, LLC, Greensboro, NC) at a rate of 0.14 kg/ha. Irrigation was utilized throughout the growing season as needed.

On August 2, 2016, forage was harvested and allowed to dry until August 5, 2016, when it was baled and wrapped as baleage. Because of rain, baling was postponed until forage was dried to proper moisture levels. Twenty-seven bales of sorghum × sudan and 24 bales of pearl millet were harvested on August 5, 2016. Forage was cut for the second harvest on August 30, 2016 and allowed to dry until August 31, 2016, when it was baled and wrapped. The second harvest produced seven bales of sorghum × sudan and eight bales of pearl millet. On October 5, 2016, forage was harvested for a third time and allowed to dry until October 6, 2016, when it was baled and wrapped. The third harvest produced eight bales of sorghum × sudan and 10 bales of pearl millet. Baleage bales were 48 in × 60 in and the average weight of pearl millet and sorghum × sudan bales were 738 kg and 799 kg, respectively. Each harvest was baled with a conventional hay baler with a mower-conditioner, transported to a designated area for storage, and wrapped with an in-line baleage wrapper. Baleage was stored outdoors until the beginning of the feeding trial on December 8, 2016. The bermudagrass hay control was harvested in the fall of 2015 from a 4-week regrowth stand and stored in a hay barn until utilized. Hay bales were 48 in × 60 in and had an average weight of 482 kg.

Experimental design and treatments

Thirty-six crossbred Angus × Hereford cows from the E.V. Smith Beef Unit herd were utilized for this experiment. Cows ranged in age from four to eight years old. Prior to the 52-day feeding trial, cows were fed corn silage and had free-choice access to a warm-season perennial pasture. Cows were initially selected based on their calving date to ensure that all calves were born within a one month period beginning on November 16, 2016 and ending on December 2, 2016. Cows were then stratified based on their initial BW on December 8, 2016 and categorized as heavy, medium, or light. Cow-calf pairs were then randomly assigned to one of the three treatments (12 cow-calf pairs per treatment). Each pasture had one heavy, one medium, and one light weight cow and either one heifer calf and two bull calves or one bull calf and two heifer calves (3 cow-calf pairs per pasture), to distribute sex of calf uniformly across treatments. Pastures used for this experiment had a bermudagrass × fescue mix as the base forage, and forages were clipped to a two-inch height to reduce selection from pasture area and ensure cow-calf pairs were consuming forages provided.

The three treatment groups included: pearl millet “Tifleaf3” baleage, sorghum × sudan “AS6402” baleage, and a bermudagrass “Tifton 85” control hay. Open and cone-shaped hay rings were also utilized across treatments as a way to measure forage waste. Each forage treatment group had two pastures utilizing an open-shaped hay ring and two pastures utilizing a cone-shaped hay ring. Therefore, the experimental design comprised of 12 pastures with: pearl millet baleage, sorghum × sudan baleage, or bermudagrass hay and either an open- or cone-shaped ring.

Data Collection and Analysis: Cow and calf performance

Cow and calf weights were recorded on Day 1, 30, and 52, and cow BCS was recorded on Day 1 and 52 of the feeding trial. Body condition scores were assigned by visual observation using a scoring system from 1 to 9, with 1 being extremely thin and 9 being extremely fat. Milk production was measured by the weigh-suckle-weigh technique at approximately 55 and 74 days postpartum. The weigh-suckle-weigh (WSW) method is a practical way to measure milk production in beef cattle and is obtained by taking the difference in calf weight before and after suckling following an interval of separation of the calf from the cow (Knapp and Black, 1941; Drewry et al., 1959; Dawson et al., 1960; Kress and Anderson, 1974). Calves were separated from their dams for 18 hours and then weighed. Calves were then allowed to suckle for 30 min, and then reweighed. Milk yield was calculated as the difference between the pre- and post- suckling weights, and milk yield was multiplied by 1.33 to estimate 24-h milk production (Kress and Anderson, 1974).

Data collection and Analysis: Forage

A 52-day feeding trial was initiated on December 8, 2016 and terminated on January 28, 2017. Cows and calves were weighed and then assigned to one of the twelve pastures based on cow weight. Four bales of pearl millet baleage, sorghum × sudan baleage, and bermudagrass hay were weighed and then placed in their designated pastures. Pearl millet and sorghum × sudan baleage were replaced every 5 days, and bermudagrass hay was replaced every 10 days throughout the feeding trial. Baleage and hay refusal was weighed prior to replacing with a new bale.

Grab samples of the forage refusal were also collected. Samples were placed in plastic, zip-closure bags and stored in a cooler for transportation to the Ruminant Nutrition Laboratory at Auburn University. Samples were refrigerated, weighed, and then dried in a 50° C oven for 48 hours. Dried, air-equilibrated samples were weighed and ground to pass a 1-mm screen in a Wiley Mill (Thomas Scientific, Philadelphia, PA). Forage concentrations of DM were determined according to procedures of AOAC (1990), and concentrations of ash were determined via combustion in a muffle furnace at 500°C (AOAC, 2000).

Core samples from each bale of baleage type were taken using a Penn State hay probe and placed in a plastic, zip-closure bag. Samples were placed in a cooler and transported to the Ruminant Nutrition Laboratory at Auburn University, where they remained in the freezer until analysis. Samples were composited based on forage type and harvest date. Ten core samples of the bermudagrass hay control were taken using a hay probe at the beginning of the feeding trial, placed in plastic zip-closure bags, and transported to the Auburn University Ruminant Nutrition labratory, where they remained in the freezer until analysis. The six bulked composite samples of baleage were freeze-dried utilizing a virTis Genesis 35L freezer dryer (SP Scientific, Gardiner, NY). Dried, air-equilibrated samples of all forage types were weighed and ground to pass a 1-mm screen.

Forage concentrations of CP and DM were determined according to procedures of AOAC (1990), and concentrations of NDF, ADF and ADL were determined sequentially according to procedures of Van Soest et al. (1991). Concentrations of ash were determined via combustion in a muffle furnace at 500°C (AOAC, 2000). Forage concentration of NDF and ADF were determined using an ANKOM 2000 fiber analyzing system (Ankom Technology Corporation, Fairport, NY. Forage in vitro true digestibility (IVTD) was determined according to the Van Soest et al. (1991) modification of the Tilley and Terry (1963) procedure using the Daisy II incubator system (Ankom Technology Corporation, Fairport, NY). Ruminal fluid was collected at 0800 h at the Auburn University College of Veterinary Medicine from a cannulated Holstein cow that had free access to bermudagrass hay and was limit-fed 15% CP supplement consisting of soy hull pellets, corn gluten feed, and whole cottonseed, plus 8oz of Megalac. Supplement fluid was stored in pre-warmed thermos containers and transported to the Ruminant Nutrition Laboratory, where it was then processed for the batch-culture IVTD procedure.

Economic Evaluation

An economic evaluation was conducted comparing the baleage × ring-feeding systems with the hay system in terms of cost per ton of DM, a total cost per cow-calf pair per day, as well as the cost of waste per cow-calf pair per day. A base price for bermudagrass hay from the USDA commodity report was used as a standard, and additional fixed costs were added in for both baleage forage treatments to produce a $/ton DM across all forage treatments. Initial and final cow weights, as well as daily consumption needs of cow-calf pairs, were used to calculate $/cow-calf pair/day and cost of feeding for 52, 90, and 150 days. Percent waste from each forage × ring treatment and percent forage intake was used to calculate cost of waste in $/cow-calf pair/day and for 52 days.

Statistical Analysis

Forage nutritive quality parameters were analyzed as a completely randomized design. Data were treated as repeated measures using PROC MIXED in SAS 9.4 (SAS Institute Inc. 2013) for forage characteristics. The statistical model included forage type, harvest date, and forage × harvest date as independent variables for forage concentrations of DM, ash, CP, NDF, ADF, ADL, and percentage of IVTD.

Forage utilization and performance responses in cows and calves were analyzed as a completely randomized design with two replicates per treatments. Data were treated as repeated measures using PROC MIXED in SAS 9.4. The statistical model included ring shape, forage type, and forage type × ring shape as independent variables for animal performance data, which included cow weigh, cow BCS, calf weight, milk production, and percent forage waste on a DM basis. The experimental unit was considered to be pen. Means were separated using least squares means with the PDIFF option of SAS. The significance level was set at $P< 0.10$ for all analysis.

RESULTS AND DISCUSSION

Temperature and precipitation

The optimum temperature for growth of pearl millet is 33 to 35 °C, with a minimum of 12 °C (Newman et al., 2010). One benefit of pearl millet is its drought tolerance compared with other forages because of its extensive root system. Sorghum × sudan has a similar growth pattern when soil temperature at 0.8 to 1.6 cm is at the ideal temperature of 18 to 21 °C. Sorghum × sudan is more severely affected by drought than pearl millet, requiring greater rainfall or irrigation during the growing season.

During the growing season, monthly mean air temperatures (Figure 1, calculated as average of daily highs and lows) for June, July, and August were comparable with 30-year averages for Shorter, AL; however, mean temperatures in September and October were 6% and 8% higher than average, respectively. Monthly precipitation (Figure 2) totals were comparable to 30-year average values in August; however, monthly totals in June, July, September and October were 35, 40, 74, and 93% less than average, respectively. Inadequate rainfall during the summer months stressed the forages and therefore required that more irrigation to be utilized. A total of 15.24 cm of irrigation was applied to the pastures throughout the growing season.

During the winter feeding period, mean air temperatures (Figure 3) for December and January were 12 and 29% higher than the 30-yr average, respectively. Likewise, total precipitation (Figure 4) for December and January was 29 and 40% higher than the 30-yr average, respectively. An increase in temperature created a mild winter in which animal demands would be lower than expected in a typical winter. The greater amount of precipitation during the trial led to more rained-exposed forage and resulted in more forage waste.

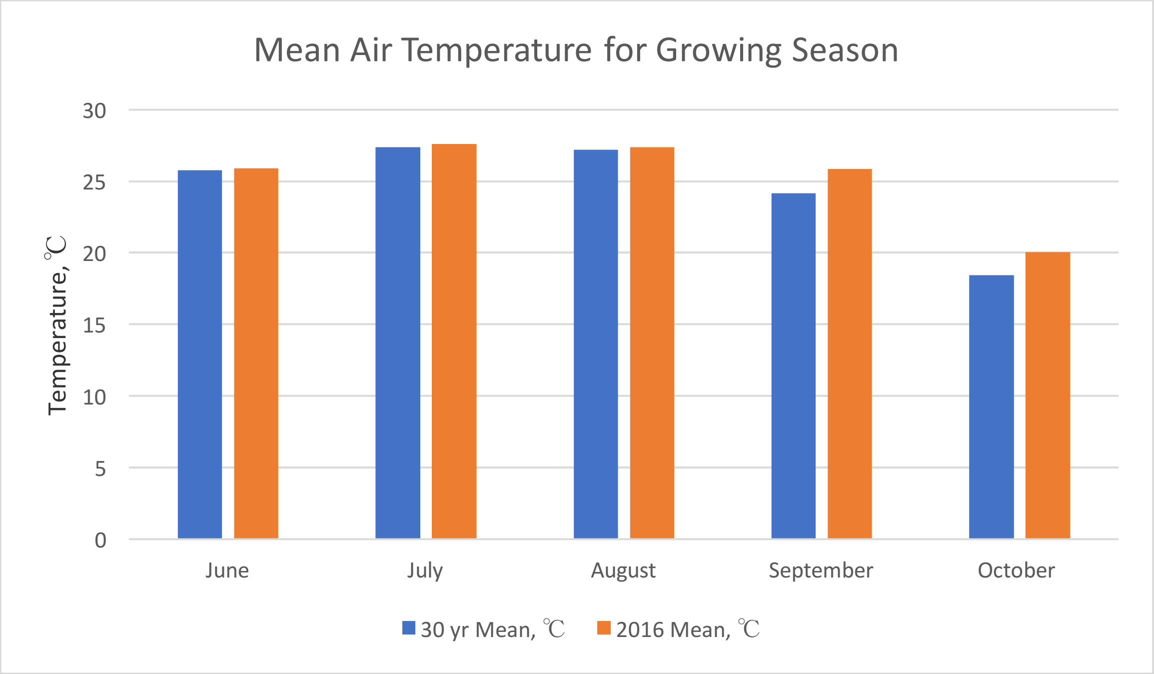

Figure 1. Monthly and 30-yr average mean air temperature from June to October at E.V. Smith Research Center, Shorter, AL.

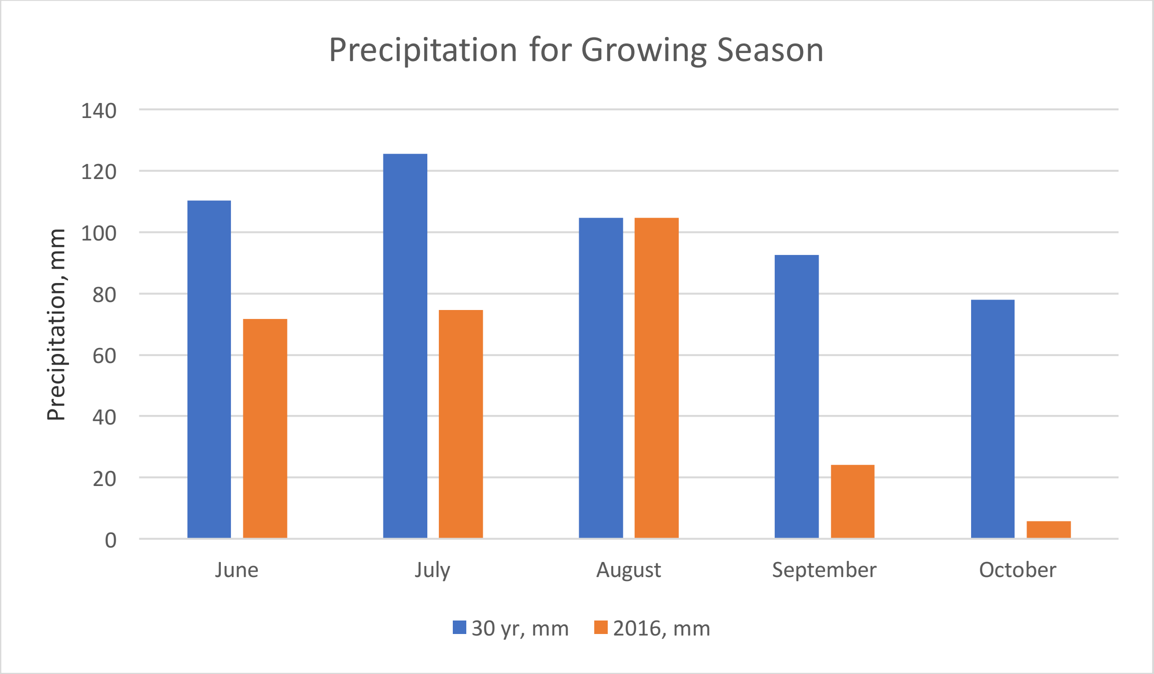

Figure 2. Monthly and 30-yr average precipitation from June to October at E.V. Smith Research Center, Shorter, AL.

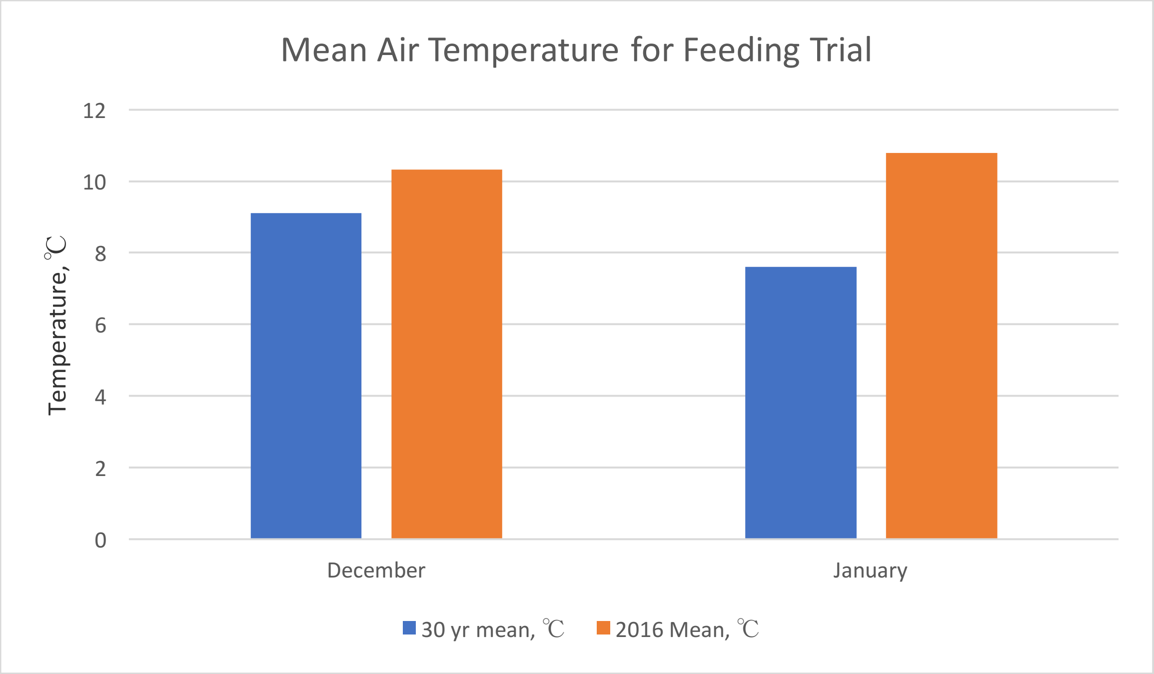

Figure 3. Monthly and 30-yr average mean air temperature for December and January at E.V. Smith Research Center, Shorter, AL.

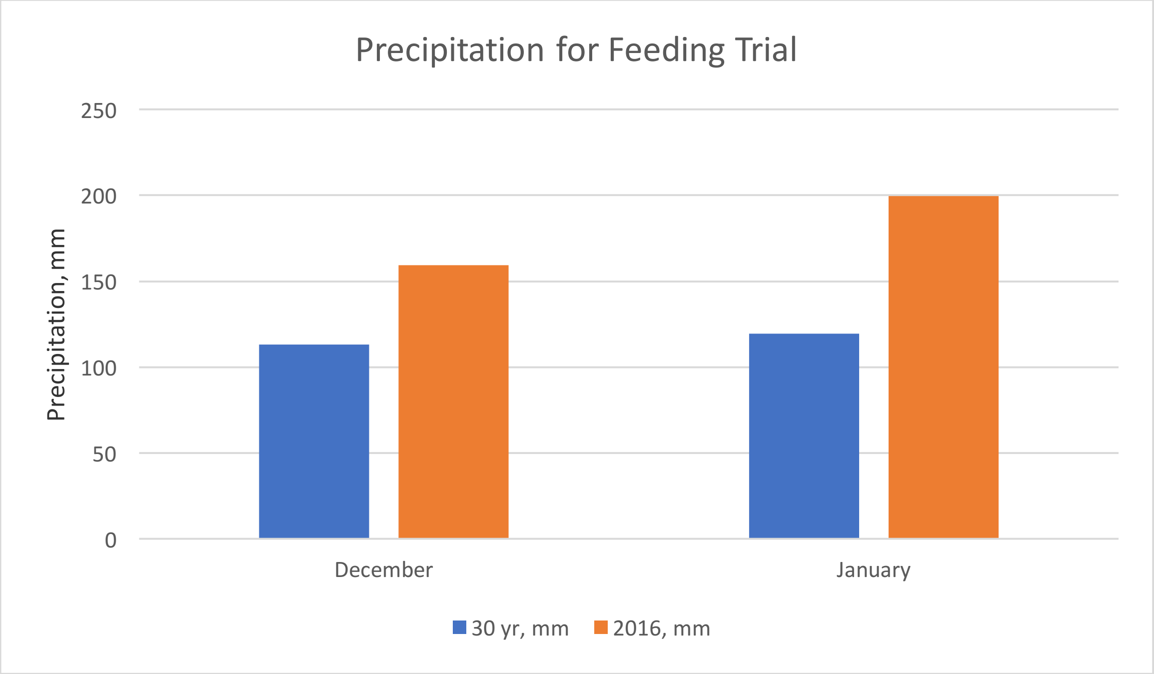

Figure 4. Monthly and 30-yr average precipitation for December and January at E.V. Smith Research Center, Shorter, AL.

Forage Quality

Forage quality parameters for PM baleage, SS baleage, and bermudagrass hay are reported in Table 1. Differences ($P < 0.10$) were observed for concentrations of ash, CP, NDF, ADF and ADL, and percentage IVTD among forage treatments.

Forage ash concentration was not different ($P = 0\ .54$) between PM baleage and SS baleage, but was less ($P < 0.01$) for bermudagrass hay. Ash consumed by animals grazing forages comes from internal sources (i.e. minerals translocated from soil) or external sources (i.e., dirt, sand), and dilutes total digestible nutrients in the forage. Concentration of ash in the aerial portion of grasses is typically 6%, whereas legumes are slightly greater at 8% (Undersander, 2016). Samples submitted to the University of Wisconsin's Soil and Forage Testing Laboratory contained an average of 12.3% ash for haylage and 10.3% for hay; the primary forage in haylage samples were alfalfa, and hay samples were a mixture of alfalfa and grass species (Undersander, 2016). Differences in these values compared with the current study are probably due to forage species. Brito et al. (2008) reported alfalfa harvested as baleage in the morning had an ash concentration of 11.3%, whereas alfalfa harvested in the afternoon had an ash concentration of 11.7%. The average ash concentration of 6% for grass species suggests that PM and SS baleage contained an additional concentration of about 4% ash, presumably contamination from external sources associated with harvesting techniques.

Crude protein concentrations of PM baleage and SS baleage were less ($P < 0.01$) than bermudagrass hay. McCormick et al. (2011) reported a different trend in CP concentrations of barn-stored bahiagrass hay and bahiagrass baleage. Their values of 12.8% and 12.9% for bahiagrass hay and baleage, respectively, are slightly lower than CP values of PM baleage, SS baleage, and bermudgrass hay baleage in the present study. On the contrary, McCormick et al. (1998) reported a difference in CP concentration between ryegrass baleage (19.8%) and indoor-stored ryegrass hay (13.1%). Brito et al. (2008) also reported a greater CP concentration than in the current study for alfalfa (18.9%) cut at sundown. Differences in CP concentrations might be attributed to superior forage quality of cool-season forages compared with warm-season forages. Concentrations of CP in pearl millet and sorghum × sudan baleages and bermudagrass hay utilized in the current study are greater than the range of 8 to 12% reported by Henning et al. (2012).

However, a different trend was observed for IVTD concentrations compared with CP concentration, in which PM baleage and SS baleage were greater ($P < 0.01$) than bermudagrass hay. The ability to harvest baleage at an earlier stage of maturity allowed for an average 17.14 percentage unit increase in digestibility compared with hay. These IVTD values are greater than previous literature reporting 58.6% and 68.0% for sorghum × sudan and pearl millet bale silage crops (McCormick et al., 2007). Han et al. (2014) reported decreasing IVTD values with increasing maturity of annual ryegrass round bale silage harvested at booting, heading, and anthesis harvest stages, for which the recommended harvesting stage for annual grasses is the boot to early head stage. As harvesting was delayed in the growing season, IVTD decreased from 79.5% at the booting stage to 67.9% at the anthesis stage. Differences in IVTD between baleage and hay are greater in this study than in previous literature. McCormick et al. (1998) reported an IVTD of 78.7% for ryegrass baleage and 71.1% for ryegrass hay. Huntington et al. (2015) reported IVTDMD values of 69.3% for switchgrass baleage and 65.4% for gamagrass baleage harvested in the afternoon.

Concentrations of NDF and ADF in PM and SS baleages were not different (*P* = 0.12 and 0.56, respectively), whereas bermudagrass hay had greater (*P* < 0.01 and 0.06, respectively) NDF and ADF concentrations. Forage concentration of NDF, which consists of hemicellulose, cellulose and lignin, is inversely related to voluntary forage DMI in ruminant animals (Van Soest, 1991). Therefore, the greater fiber concentration in hay presumably restricts the amount of forage voluntarily consumed by the animal to a greater extent. Values for PM and SS baleages utilized in this study are within the range of 55 to 70%, whereas bermudagrass hay was greater than the range of 63 to 68% reported by Henning et al. (2012). Forage concentrations of NDF in this study are similar to ryegrass harvested as baleage (56.2%) and hay (70.5%) reported by McCormick et al. (1998). In a forage baleage nutritive quality analysis comparing ryegrass, a cool-season forage, and multiple warm-season forages such as crabgrass/ signalgrass, sorghum/millet, bermudagrass, and bahiagrass conducted at the LSU Southeast Research Station, NDF concentrations were greater in bermudagrass (73.2%), bahiagrass (68.9%), and sorghum/millet (68.5%) than ryegrass baleage (61.4%). Not only does nutritive value vary among forage species, but also storage method utilized. McCormick et al. (2011) reported similar CP and greater fiber concentrations for outdoor-stored bahiagrass hay than bahiagrass hay stored indoors or as baleage.

Concentration of ADF, which consists of cellulose and lignin, is inversely related to forage DM digestibility (Van Soest, 1991). The ADF concentrations of PM and SS baleages from this study are lower than that of bahiagrass baleage (39.5%) reported by McCormick et al. (2011), and slightly greater than that of alfalfa baleage (29%) reported by Brito et al. (2008). These latter values are expected because cool-season forages are more digestible than warm-season forages, and annuals tend to surpass perennial forages in regards to digestibility. Borreani et al. (2007) reported a similar trend that late-harvested orchard grass-fescue-clover mix hay had a greater ADF concentration (42.2%) than early-harvested haylage (38.6%), whereas McCormick et al. (2011) concluded that bahiagrass baleage and barn-stored hay had similar ADF concentrations of 39.5% vs. 38.8%, respectively. Concentrations of ADF in PM and SS baleage are less than the range of 35 to 40%, and bermudagrass hay is within the range of 38 to 40% reported by Henning et al. (2012), indicating that forage utilized in this study had less fiber than average pearl millet and sorghum × sudan crops evaluated elsewhere previously.

Comparing the bermudagrass hay utilized in this experiment with 16,000 producer-submitted bermudagrass hay samples analyzed at the University of Georgia Feed and Environmental Water Laboratory from 2003 to 2015 (average protein, 12%; average TDN, 56%), it was clearly superior to the majority of hay being utilized in the Southeastern region, most likely reflecting forage being overly mature at harvest, a consequence of unfavorable hay drying conditions during the early growing season, or differences in forage storage method utilized.

Acid detergent lignin is a plant structural phenolic polymer that is not digested by the microbes in the rumen. Lignin encrusts the cellulose in the plant secondary cell wall, impairing the digestibility of the forage and most likely decreasing the amount of forage the animal consumes (Scaglia et al., 2012). Concentration of ADL was greater ($P < 0.02$) for bermudagrass hay than PM and SS baleage. Concentrations of ADL in PM baleage and SS baleage are slightly lower than lignin concentrations from switchgrass (5.35%) and gamagrass (5.23%) harvested as baleage in the afternoon (Huntington et al., 2015). McCormick et al. (2007) reported lignin values of 3.46% for pearl millet baleage and 5.14% for sorghum × sudan baleage. The ADL value for PM baleage utilized in this study is slightly greater, and that of SS baleage is slightly lower than reported in previous literature. Differences in lignin concentrations can be attributed to forage varieties with and without the brown mid rib (BMR) trait. Varieties possessing the BMR trait are typically lower in lignin, making them more digestible than non-BMR varieties. There has been an increasing trend for the use of BMR technologies in sorghums and other silage crops in the southeastern region in recent years. Furthermore, the lignin concentration of 7.12% for bermudagrass hay utilized in this study is slightly higher than the concentration of 5.0% reported by Scaglia et al. (2012).

Forage CP concentrations across all forage treatments were adequate in meeting the CP requirements (9.5%) of a 615-kg mature, lactating beef cow during peak lactation(NRC, 2016). Similarly, percentage IVTD across all forage treatments was adequate in meeting the IVTD requirements (58%) for lactation (NRC, 2016). Cattle consuming the bermudagrass hay could presumably have increased performance with supplementation because of a lower IVTD percentage and higher fiber concentration.

Table 1. Chemical composition and in vitro true digestibility (IVTD) of experimental forages

	Item (%, DM basis)					
Forage	Ash	CP	IVTD	NDF	ADF	ADL
PM Baleage	10.3^{a}	14.0^{b}	74.0^{a}	58.8^{b}	33.9^{b}	4.5^{b}
SS Baleage	9.9^{a}	13.9^{b}	78.0^{a}	55.2^{b}	32.5^{b}	3.8^{b}
Bermuda Hay	5.7^{b}	15.2^{a}	58.9^{b}	74.4^{a}	39.2^{a}	7.1^{a}
Mean	8.6	14.4	70.3	62.8	35.2	5.1
SEM	0.5	0.3	2.5	1.4	1.6	0.6

[a,b]Within a column, means without a common superscript differ ($P < 0.10$).

Forage Waste

During the 52-day feeding trial, there were no forage × ring interactions (*P* > 0.96) for forage waste (Table 2). There were also no differences (*P* > 0.35) between open or cone-shaped hay ring treatments. The percent of waste from PM baleage and SS baleage was greater (*P* < 0.02) than that from bermudagrass hay. These findings may be due to preference for hay over baleage in cooler temperatures (McCormick et al., 1998). Also, longer forage particle length of these warm-season annuals that has been shown to alter eating and chewing behavior (Jastic and Murphy, 1983) and decrease DMI in ruminant diets (DeBoever et al., 1993). The conclusions of this study contrast what is reported in previous literature.

Lane (2009) reported forage waste at the feeder to be as much as 25% for hay, whereas baleage resulted in 10% or less waste. These differences may be due to the quality of hay as well as storage method utilized. Martin et al. (2014) reported a similar trend in refusal rates of 10% from calves consuming bermudagrass hay compared with 5% from calves consuming rye, ryegrass, or bermudagrass baleage. Sexton et al. (2013) observed a difference in percent hay waste utilizing a cone shape (6.8%) and a conventional style (14.5%) hay ring. Wells et al. (2011) also observed greater amounts of hay waste utilizing an open-bottom steel ring (20.5%) compared with a modified cone ring (5.3%). Moore and Sexten (2015) reported similar results with open feeders having the greatest waste (19.2%) and cone feeders having the least waste (8.9%) when utilizing dry hay. However, they found forage waste from baleage was not affected by feeder design. Previous literature indicates that cone-shaped rings are superior to open-shaped rings when dry hay is fed. The conclusions of this study suggests that cone-shape rings are similar to open-shaped rings for reducing forage waste when baleage is fed. Also, increased rate of refusal for baleage compared with hay can be attributed to increased rainfall during the feeding trial, resulting in spoilage from rained-exposed forage.

Table 2. % Forage waste, (% of fed, DM basis)

	Ring Type[1]		
Forage Type	C	O	Mean
PM Baleage	22.7	26.0	24.3[a]
SS Baleage	17.4	22.2	19.8[a]
Bermuda Hay	5.6	8.1	6.8[b]
Mean	15.2	18.8	

[a,b] Within a column, means without a common superscript differ (*P* < 0.10; SEM = 4.3).

[1] C = cone-shaped ring; O = open-shaped ring.

Animal Performance

Cow Performance: Weight and BCS

Simple means of cow initial BW (613 ± 5.38), final BW (541± 5.47), initial BCS (6.06 ± 0.08), and final BCS (5.46 ± 0.05) are shown in Table 3 for each treatment. There were no forage × ring interactions ($P > 0.67$) for cow initial BW. Cow initial BW differed ($P < 0.08$) between cone and open rings, with cows on pasture utilizing a cone-shaped ring weighing 13.23 kg more than cows utilizing an open-shaped ring. There was also a difference ($P < 0.01$) in initial cow BW among forage treatments such that cows consuming bermudagrass hay were the heaviest, SS baleage were intermediate, and cows consuming PM baleage weighed the least.

At the end of the 52-day feeding trial, there were no forage × ring interactions ($P > 0.72$) for cow final BW. There was a difference ($P < 0.08$) in final cow BW for ring shape, with cows utilizing a cone-shaped ring weighing 13.1 kg more than cows utilizing an open-shaped ring. As with initial BW, there was a difference ($P < 0.01$) in final cow BW among forage treatments such that cows consuming bermudagrass hay and SS baleage weighed more than cows consuming PM baleage. Cows consuming PM baleage, SS baleage, and bermudagrass hay lost 69.6, 69.2, and 76.2 kg, respectively, during the feeding trial. There was no difference ($P > 0.78$) in cow weight loss among forage treatments or ring shape in this study. Cows in pastures utilizing a cone-shaped ring lost 71.7 kg, whereas cows utilizing an open-shaped ring lost 71.6 kg. Body weight and BCS losses in the present study were greater those of lactating Holstein cows consuming bahiagrass barn-stored hay and baleage during a 42-day feeding trial in which cows consuming bahiagrass hay had a BW loss of 19.1 kg and a BCS loss of 0.2 units, whereas cows consuming bahiagrass baleage had a BW loss of 4.8 kg and BCS loss of 0.1 units (McCormick et al., 2011). Differences in results can be attributed to the addition of concentrate fed to dairy cows with the bahiagrass forage in order to meet their daily requirements.

No forage × ring interactions, or differences among forage or ring-shape treatments were detected ($P > 0.19$) for cow initial and final BCS. Total BCS loss for cows consuming PM baleage, SS baleage, and bermudagrass hay was 0.5, 0.6, and 0.7 units, respectively. Cows utilizing a cone-shaped ring lost 0.5 units of BCS, whereas cows utilizing an open-shaped ring lost 0.7 units of BCS by the end of the trial. There was no difference ($P > 0.46$) in BCS loss among forage or between ring-shape treatments in this study.

McCormick et al. (2011) reported that cow BW, BCS, and study-long differences in BW and BCS were not different ($P > 0.05$) for lactating Holstein cows among forage conservation systems that included barn-stored and outdoor-stored bahiagrass hay and bahiagrass baleage. Additionally, McCormick et al. (1998) compared ryegrass stored as baleage, haylage, or hay fed to lactating dairy cows and reported no treatment differences for cow weight or BCS; however, they did report greater final cow weights than initial, indicating that a portion of energy consumed was partitioned toward weight gain for all treatments. These findings differ from those in the current study in which cows lost weight across all forage treatments. McCormick et al. (1998) reported lower BCS values at the conclusion of their study, in agreement with the findings of the current study.

Hancock et al. (2010) reported that ADG of replacement heifers fed ryegrass baleage was greater than bermudagrass hay and ryegrass hay. Heifers consuming ryegrass baleage had an ADG of 0.9 kg, whereas heifers consuming bermudagrass hay and ryegrass hay had an ADG of 0.7 and 0.6 kg, respectively. Body weight and BCS loss from cows utilized in this study were within the normal range for lactating mature beef cows in a winter feeding system. During a fall-winter forage gap, supplemented forages are needed in order to maintain animal needs. It is not common for lactating beef cows to gain weight during these forage gaps, but rather maintain or lose half a BCS until forage is available and the animals are able to return to their maintenance weight and BCS.

Table 3. Cow BW (kg) and BCS

		Ring type[1]		
Item	Forage	C	O	Mean
Initial BW	PM Baleage	601.8	581.4	591.6^{z}
	SS Baleage	617.6	611.2	614.4^{y}
	Bermuda Hay	639.2	626.3	632.8^{x}
	Mean	619.5^{a}	606.3^{b}	
Final BW	PM Baleage	532.2	511.8	522.0^{w}
	SS Baleage	550.0	540.5	545.3^{v}
	Bermuda Hay	561.3	551.9	556.6^{v}
	Mean	547.8^{c}	534.7^{d}	
Initial BCS	PM Baleage	6.0	5.8	5.9
	SS Baleage	6.0	6.2	6.1
	Bermuda Hay	6.2	6.2	6.2
	Mean	6.1	6.1	
Final BCS	PM Baleage	5.5	5.4	5.5
	SS Baleage	5.6	5.3	5.5
	Bermuda Hay	5.6	5.3	5.5
	Mean	5.6	5.4	

^{a,b} Within a row, means without a common superscript differ (*P* < 0.10; SEM = 13.7).
^{x,y,z} Within a column, means without a common superscript differ (*P* < 0.10; SEM = 16.8).
^{c,d} Within a row, means without a common superscript differ (*P* < 0.10; SEM = 13.9).
^{v,w} Within a column, means without a common superscript differ (*P* < 0.10; SEM = 17.0).
[1] C = cone-shaped ring; O = open-shaped ring.

Cow Performance: Milk Production

There were no forage × ring interactions, or differences among forage or between ring-shape treatments ($P > 0.27$) for milk production in this study (Table 4). The average amount of milk produced by each cow during a 24-h period was 7.0 kg. Using the weigh-suckle-weigh (WSW) method, Williams et al. (1979) reported mean 24-h milk production using 4-h, 8-h, and 16-h calf-separation intervals, respectively, to be 9.2, 7.6, and 5.9 kg. Values for 24-h milk production in this study using an 18-h calf-separation interval are slightly greater than those from previous studies, but well within the normal range of milk production for a mature beef cow (NRC, 2016). McCormick et al. (1998, 2011) observed that actual milk yield did not differ ($P > 0.05$) between cows consuming cool-season or warm-season baleage and cows consuming hay. Dairy cows consuming haylage produced more milk (1.7 kg/d) and more 3.5% fat-corrected milk (1.5 kg/d) than cows consuming hay that had a delayed harvest of 4 weeks, where forages in both systems were an orchard grass-fescue-clover mix.

Mature 615-kg beef cows producing 7.0 kg of milk per day require a diet containing 59.1% TDN and 10.3% CP at 2 months postpartum (NRC, 2016). Across all forage treatments, mean percentage CP and IVTD were 14.4% and 70.3%, respectively, which met the requirements of mature lactating cows throughout the study. Milk production at d 30 and 52 were not different ($P < 0.05$).

Calf Performance

Means of calf initial BW (50.2 ± 1.6), final BW (108.0 ± 2.4), and BW gain (57.8 ± 1.4) are shown in Table 4. There was no forage × ring interaction or effect of ring shape ($P > 0.35$) on calf initial BW. Calf initial BW differed ($P < 0.08$) among forage treatments, with calves on the bermudagrass hay treatment weighing the most, SS baleage being intermediate, and calves on the PM baleage treatment the lightest. There were no forage × ring interactions, or differences among forage or between ring-shape treatments ($P > 0.17$) in calf final weight. Furthermore, there was no forage × ring interaction or effect of forage type ($P > 0.40$) in calf weight gain. Calf weight gain differed ($P < 0.01$) between ring-type treatments, with calves on the open-shaped ring treatment weighing 6.1 kg more than calves on the cone-shaped ring treatment.

There is no published research that has reported weight gain of calves nursing cows consuming baleage vs. conventional dry hay. There was no difference in calf gain among forage treatments, and all calves had an ADG of 1.1 kg/day during the 52-day feeding trial. This value is greater than that of a nursing beef calf that should typically have an ADG of 0.7 to 0.8 kg/day (McCann, 2012). Therefore, all forage treatments utilized in this study provided adequate nutritive quality to enable milk production that supports calf growth.

Table 4. Calf performance and 24-h cow milk production (kg)

Item	Forage	Ring Type[1] C	Ring Type[1] O	Mean
Calf initial BW	PM Baleage	49.2	45.4	47.3^{y}
	SS Baleage	50.4	49.4	49.9^{xy}
	Bermuda Hay	53.9	53.1	53.5^{x}
	Mean	51.2	49.3	
Calf final BW	PM Baleage	105.3	105.3	105.3
	SS Baleage	105.2	109.5	107.3
	Bermuda Hay	107.2	115.7	111.5
	Mean	105.9	110.2	
Total calf BW gain	PM Baleage	56.1	59.9	58.0
	SS Baleage	54.8	60.0	57.4
	Bermuda Hay	53.3	62.7	58.0
	Mean	54.7^{b}	60.9^{a}	
Cow milk production[2]	PM Baleage	6.1	6.4	6.3
	SS Baleage	10.6	6.7	8.7
	Bermuda Hay	5.4	8.0	6.7
	Mean	7.4	7.1	
Cow milk production[3]	PM Baleage	6.0	8.6	7.3
	SS Baleage	6.5	5.4[7]	6.0
	Bermuda Hay	6.6	7.5	7.1
	Mean	6.4	7.2	

[a,b] Within a row, means without a common superscript differ ($P < 0.10$; SEM = 4.9).

[x,y,z] Within a column, means without a common superscript differ ($P < 0.10$; SEM = 3.6).

[1] C = cone-shaped ring; O = open-shaped ring.

[2] Determined by weigh-suckle-weigh method at d 32.

[3] Determined by weigh-suckle-weigh method at d 52.

[7] 5 Observations reported for this treatment because of a negative milk production recorded

Economics of Winter Feeding Systems

An economic evaluation comparing forage treatments and forage × ring feeding systems was conducted (Table 5). Variables included cow performance, daily forage consumption needs, and percent waste among forage treatments and ring shape. Costs per ton DM were 16 and 24% greater for PM and SS baleage, respectively, than bermudagrass hay. It cost \$16.54 and \$26.46 more to feed each cow-calf pair for the 52-day feeding trial utilizing PM baleage and SS baleage, respectively, compared with the bermudagrass hay. As number of days increase to 90 and 150 days, the cost difference between baleage treatments and the hay treatment become greater. The cost of feeding would be \$28.62 and \$45.80 more for PM and SS baleage, respectively, compared with bermudagrass hay for a 90-day feeding period and \$47.71 and \$76.33 for a 150-day period. This feeding period would be reflective of industry practice for winter feeding in the southeast region. Pruitt et al. (2013) reported cost savings of \$46.96 per cow for a baleage system utilizing an in-line wrapper and 5% storage loss compared with harvesting hay and storing outdoors with 25% storage loss. Differences reported in this study could be due to greater amounts of forage wasted for both baleage treatments compared with the hay treatment. Cost savings (\$/cow-calf pair for 52 days) from utilizing a cone-shaped hay ring rather than an open-shaped hay ring were \$3.44, \$5.40, and \$2.15 for PM baleage, SS baleage, and bermudagrass hay, respectively. Because of the greater percentage of waste from baleage treatments, the cost of waste was \$19.73 and \$18.07 more for PM and SS baleage than the hay treatment utilizing an open-shaped hay ring. Cost among systems may be more similar if baleage was compared to hay stored outdoors, rather than indoor stored hay utilized in this study.

This economic evaluation suggests that a producer with herd size of less than 50 cows cannot justify harvesting forage as baleage because of the increased cost of production and similar animal performance across forage treatments. This study also suggests the purchase of a cone-shaped hay ring is not a financially responsible decision because the percent of waste does not make up for the additional $340 cost of the cone-shaped hay ring.

Table 5. Estimated cost associated with PM and SS baleage or bermudagrass hay.

		Treatments[1]		
Item	Ring Type[2]	PM baleage	SS baleage	Bermuda hay
$/ton DM	-	$124	$136	$104
$/cow-calf pair/day	-	$1.97	$2.16	$1.65
Cost of feeding for 52 days	-	$102.55	$112.47	$86.01
Cost of waste, $/pair/day	-	-	-	-
	Open	$0.51	$0.48	$0.13
	Cone	$0.45	$0.38	$0.09
Cost of waste, $/pair for 52 days	-	-	-	-
	Open	$26.68	$25.02	$6.95
	Cone	$23.24	$19.61	$4.79

[1] PM baleage = pearl millet baleage; SS baleage = sorghum × sudan baleage; Bermuda hay = bermudagrass hay.

[2] C = cone-shaped ring; O = open-shaped ring.

SUMMARY AND CONCLUSIONS

Results of this study suggest that PM and SS baleage are superior in nutritive value to bermudagrass hay, indicated by the forage quality parameters. PM and SS baleage had greater percentage IVTD and lower NDF, ADF, and ADL concentrations compared with bermudagrass hay. Because all forage treatments utilized in this study met the CP and IVTD requirements of a 615-kg mature, lactating beef cow, similar animal performance was reported among the three forage treatments. There were no differences ($P > 0.10$) in cow weight or BCS loss, cow milk production, or total calf BW gain among the forage treatments. The additional cost of machinery and plastic wrap needed to harvest forage as baleage should be compensated with increased animal performance for a producer to profit from this management practice. Because there were no differences ($P > 0.10$) in animal performance, this study suggests it would not be economical to harvest summer annual forage as baleage to supplement lactating beef cows during a fall-winter forage gap. Harvesting summer annual forage as baleage might be economical for a producer with cattle having higher CP and IVTD requirements, such as growing steers or lactating dairy cows; as well as, a herd size greater than the one utilized in this study. Results of this study suggest purchasing a cone-shaped hay ring is not an advantageous business decision because the percent of forage waste and animal performance did not differ ($P > 0.10$) between the cone and open-shaped hay rings. PM and SS baleage did have an increased ($P < 0.10$) forage waste compared with bermudagrass hay, indicating that the ring shape could have economic advantages for dry hay but not for baleage.

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APPENDIX I

Chemical composition and in vitro true digestibility (IVTD) of experimental forages by harvest date (%, DM basis)

	Item					
Forage	Ash	CP	IVTD	NDF	ADF	ADL
PM Baleage H1	10.94	14.29	65.72	63.43	38.86	6.58
PM Baleage H2	10.84	14.36	79.58	56.94	31.48	3.57
PM Baleage H3	9.08	13.45	76.70	55.97	31.31	3.36
PM Mean	10.29	14.03	74.00	58.78	33.88	4.50
SS Baleage H1	10.70	14.61	76.91	56.56	35.19	4.17
SS Baleage H2	9.96	13.72	80.14	54.30	31.45	3.42
SS Baleage H3	8.95	13.45	76.97	54.64	30.74	3.76
SS mean	9.87	13.93	78.00	55.17	32.46	3.78
Bermuda Hay	5.74	15.23	58.86	74.42	39.20	7.12