Performance of growing beef cattle consuming bahiagrass hay treated with calcium oxide and molasses

Francine M. Ciriaco,†‡||, Darren D. Henry,‡ Carla D. Sanford,|| Luara B. Canal,† Jose C. B. Dubeux Jr,† and Nicolas DiLorenzo†,1

†North Florida Research and Education Center, University of Florida, Marianna, FL 32446-7906, USA
‡Department of Animal and Dairy Science, University of Georgia, Tifton, GA 31793, USA
||Department of Animal and Range Sciences, Montana State University, Bozeman, MT 59717-2900, USA

ABSTRACT: Two experiments were conducted to evaluate the effects of Pensacola bahiagrass (Paspalum notatum) hay treated with calcium oxide (CaO) and molasses on performance of growing beef cattle supplemented or not with cottonseed meal. In Exp. 1, growing Bos indicus influenced heifers (n = 59; 250 ± 29 kg body weight [BW]) and steers (n = 37; 256 ± 45 kg BW) were used. In Exp. 2, heifers (n = 56; 249 ± 26 kg BW) and steers (n = 8; 249 ± 20 kg BW) from Exp. 1 were used. Both experiments were randomized complete block designs and consisted of 56-d periods in which cattle were weighed every 14 d. On day 0, cattle were weighed after a 16-h water and feed withdrawal, stratified by sex, breed, and BW, and blocked by initial BW. Cattle were allotted to 24 and 16 dormant bahiagrass pastures (1.34 ha each) in Exp. 1 and Exp. 2, respectively. Pastures were located in two different areas within 0.52 km of each other and were stratified by location and randomly assigned (n = 8 pastures/treatment) to treatment. In Exp. 1 treatments were: 1) untreated dry hay (DH); 2) hay treated with 10% molasses (DM basis) + water (56% DM; MOL); or 3) hay treated with 5% CaO (DM basis) + 10% molasses (DM basis) + water (65% DM; CAO). In Exp. 2 only treatments MOL and CAO were applied, and cottonseed meal was provided at 0.3% of cattle BW/d (as fed basis). In both experiments, data were analyzed using pasture as the experimental unit. The model included the fixed effects of treatment, sex, and their interaction (Exp. 1). Location and block were included as random effects. In both experiments, initial and final BW were not affected by treatment (P ≥ 0.362 and P ≥ 0.283, respectively) or sex (P ≥ 0.512 and P ≥ 0.495, respectively) and no treatment × sex interaction was observed in Exp. 1 (P > 0.05). Additionally, no effects of treatment (P ≥ 0.515), sex (P ≥ 0.285), or treatment × sex interaction (Exp. 1; P = 0.582) were observed on average daily gain (average of −0.03 kg in Exp. 1 and 0.537 kg in Exp. 2). Bahiagrass hay treated with molasses alone or in combination with CaO failed to improve performance of growing beef cattle. However, when protein supplementation via cottonseed meal was provided, cattle did not experience weight loss.

Key words: alkali treatment, bahiagrass hay, beef cattle, cottonseed meal, molasses, performance

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†Corresponding author: ndilorenzo@ufl.edu
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INTRODUCTION

Many researchers have focused on increasing digestibility of poor-quality forages and roughages that would usually go to waste by performing chemical treatment with alkali such as NaOH (Chaudhry and Miller, 1996; Mishra et al., 2000), NH₃ (Mason et al., 1988), and Ca(OH)₂ (Zaman and Owen, 1995; Wanapat et al., 2009), with NaOH being the standard chemical that promoted the greatest effects on fiber degradability. More recently, due to animal, environmental, and human safety concerns, attention has been given to the alkali CaO (Euken and Dahlke, 2014; Peterson et al., 2015a), and it has been observed that the efficacy is similar to that of NaOH (Watson et al., 2015).

Beef cattle operations in Florida and the southeastern United States rely primarily on grazed and conserved forages to supply dietary nutrients; however, the predominant forages in this region can have elevated fiber contents and may be deficient in both crude protein (CP) and energy, thus supplementation is needed to maximize animal performance and reach a desired level of production (Bowman et al., 1995).

Chemical treatment of poor-quality roughages (e.g., crop residues) with CaO has been extensively researched considering cattle performance when treated residues replaced corn in finishing (Shreck et al., 2013; Chapple et al., 2015; Shreck et al., 2015) or backgrounding (Shreck et al., 2014; Peterson et al., 2015b) diets. The literature varies indicating either no negative effects and similar performance in cattle consuming diets with treated residues (Chapple et al., 2015; Shreck et al., 2015) or increases in average daily gain (ADG) and gain to feed ratio in cattle consuming treated residues in high-forage growing diets (Peterson et al., 2015b).

To the best of the authors’ knowledge, no data has been published regarding treating poor-quality hay, such as Pensacola bahiagrass (Paspalum notatum) hay, with CaO and feeding it as the sole forage component in growing cattle diets to evaluate animal performance. Therefore, it was hypothesized that CaO treatment would improve fiber digestibility of Pensacola bahiagrass hay. With the addition of molasses, it was hypothesized that beef cattle performance would increase due to a combination of increased forage digestibility and additional energy to the diet (Exp. 1). By supplementing with cottonseed meal, it was hypothesized that beef cattle performance would increase due to a combination of increased forage digestibility, and additional energy and protein to the diet (Exp. 2). The objectives were the following: Exp. 1—to evaluate the effects of Pensacola bahiagrass hay treated with 5% CaO and 10% molasses on beef cattle performance; Exp. 2—to evaluate the effects of Pensacola bahiagrass hay treated with 5% CaO and 10% molasses plus protein supplementation via cottonseed meal on beef cattle performance. An additional objective was to assess effectiveness of CaO treatment by determining in vitro organic matter digestibility (IVOMD) of the bahiagrass hay treated or not provided to cattle in Exp. 1.

MATERIALS AND METHODS

All procedures involving animals were approved by the University of Florida Institutional Animal Care and Use Committee (Protocol # 201508733).

Experiment 1—Experimental Design, Animals, and Treatments

Growing Bos indicus influenced crossbred heifers (n = 59; 250 ± 29 kg body weight [BW]; average BW ± SD) and steers (n = 37; 256 ± 45 kg BW) were used in a randomized complete block design at the University of Florida – North Florida Research and Education Center Beef Unit (UF-NFREC BU) in Marianna, FL. Animals used were part of the university’s herd and during the spring had been previously administered vaccinations against infectious bovine rhinotracheitis, bovine virus diarrhea Types 1 and 2, para influenza 3 (PI3), and bovine respiratory syncytial virus (BRSV; Bovi-Shield GOLD FP 5, Zoetis, Parsippany, NJ), and clostridial diseases (Ultrabac 8, Zoetis). During the spring and again in September, an antiparasitic (Dectomax Pour-On, Zoetis) was applied to all cattle. The experiment consisted of a 13-d adaptation period followed by a 42-d data collection period. On day 0, cattle were stratified by sex, breed, and BW, and blocked by initial BW. Cattle were then allotted to 24 dormant bahiagrass pastures (1.34 ha each; one pasture with 3 heifers, one pasture with 5 steers, 11 pastures with 4 heifers, and 11 pastures with 4 steers), which were located in two different areas of the UF-NFREC BU within 0.52 km of each other. The two locations were termed R-pens (n = 11; pastures per location) and South Circle (n = 13). Pastures were stratified by location and randomly assigned (n = 8 pastures/treatment) to 1 of 3 treatments: 1) untreated dry hay (DH); 2) hay treated with 10% molasses (dry matter [DM] basis) + water (to 65% DM; MOL); or 3) hay treated with 5% CaO (DM basis) + 10% molasses (DM basis) + water (to 65% DM; CAO).

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The experiment started on December 29; therefore, there was no residual forages in the pastures and bahiagrass hay from treatments was the only forage available, which was provided ad libitum to cattle.

**Experiment 2—Experimental Design, Animals, and Treatments**

Heifers (n = 56; 249 ± 26 kg BW) and steers (n = 8; 249 ± 20 kg BW) from Exp. 1 were used in a second experiment in a randomized complete block design at the UF-NFREC BU. The experiment consisted of a 14-d adaptation period followed by a 42-d data collection period. On day 0, cattle were stratified by sex, breed, and BW, and blocked by initial BW. Cattle were then allotted to 16 of the same dormant bahiagrass pastures described in Exp. 1 (n = 8 R-pens and n = 8 South Circle; 4 animals/pasture). Pastures were stratified by location and randomly assigned (n = 8 pastures/treatment) to MOL or CAO; therefore, animals from all treatments in Exp. 1 were allotted to both treatments in Exp. 2. Cottonseed meal (CSM) was provided at 0.3% of cattle BW/d (as fed basis). The delivery of the weekly amounts of CSM for all animals in the pasture was performed three times per week (Monday, Wednesday, and Friday). Amounts of CSM were adjusted every 2 wk when cattle were weighed. The selection started on March 7, when there were still no residual forages in the pastures and bahiagrass hay from treatments was the only forage available, which was provided ad libitum to cattle.

**Treatment of Bahiagrass Hay**

With a tractor and feed wagon, in Exp. 1, small round bales (average 219 ± 18 kg as is; 178 ± 15 kg DM) and in Exp. 2, small (average 225 ± 16 kg as is; 183 ± 14 kg DM) and large (average 510 ± 16 kg as is; 417 ± 25 kg DM) round bales were individually weighed and core samples were taken of each bale to calculate DM. For both experiments, treatment of hay was performed in the same manner. Amounts of sugar cane blackstrap molasses (donated by Quality Liquid Feeds, Inc., Dodgeville, WI) and CaO (HI CAL QUICKLIME – FOUNDRY, 89% available CaO; Lhoist North America of Alabama, Calera, AL) were weighed for each bale at 10 and 5% of the bale DM, respectively. In 20-liter buckets, with the aid of a paint mixer and electric hand drill, molasses and CaO were mixed with the water needed to reach a final bale DM of 65%. The bales were placed on the ground, on their flat side, and the mixture of molasses, CaO, and water was poured as quickly as possible before the bale was placed back on its round side, to minimize liquid runoff. Bales were allowed to sit uncovered for at least 7 d, but no longer than 14 d, before cattle feeding. The choice of 5% CaO was based on what has been most commonly reported in the literature when treating crop residues (Shreck et al., 2011; Shreck et al., 2015). The amount of molasses chosen (10% of bale DM) was based on recommendations from the company Quality Liquid Feeds when applying their liquid feed products directly to harvested forages. The amount of water to reach 65% DM was chosen to minimize liquid runoff and losses.

In both experiments, before a new bale was provided to each pasture, core samples from each bale were taken with a hay probe (Best Harvest, Bay City, MI) and electric hand drill to measure DM concentration before cattle feeding.

**Sampling Procedures**

**Body weight and blood sampling** To measure ADG in Exp. 1 cattle were weighed on day 0, 13, 27, 41, and 56. In Exp. 2, cattle were weighed on day 0, 14, 28, 42, and 56 and interim weights were used to adjust amounts of CSM to be delivered. The following procedures were performed in the same manner for both experiments. On day 0 and 56, cattle were weighed after a 16-h water and feed withdrawal to obtain shrunk initial and final BW, while interim weights were recorded as full measurements. During the same time of BW measurements, a blood sample was collected via jugular venipuncture into 10-mL evacuated tubes containing Na heparin (BD Vacutainer, Franklin Lakes, NJ). Tubes were inverted 10 times, immediately placed on ice, and subsequently centrifuged for 15 min at 4,000 × g at 4 °C. Plasma was then transferred to labeled polypropylene tubes (12 × 75 mm; Fisherbrand; Thermo Fisher Scientific Inc., Waltham, MA) and stored at −20 °C for further analysis of plasma urea N (PUN).

**Laboratory analyses** All protocols and procedures used for sample analyses were identical throughout both experiments. Plasma was analyzed for PUN using a quantitative colorimetric kit (B7551-120; Pointe Scientific Inc., Canton, MI) according to the manufacturer instructions.

**Nutritional composition of hay and cottonseed meal** Subsamples of core samples from hay bales taken before cattle feeding in both experiments were analyzed in-house for DM concentration in a
105 °C forced-air oven for 24 h. The remainder of the core samples were dried in a 55 °C forced-air oven for 72 h, composited within treatment, ground to pass a 2-mm screen in a Wiley mill (Thomas Scientific, Swedesboro, NJ), and sent to a commercial laboratory (Dairy One Forage Laboratory, Ithaca, NY) for analysis of organic matter, CP, neutral detergent fiber, acid detergent fiber, lignin, and Ca concentrations.

**In vitro organic matter digestibility** In order to test the effectiveness of bahiagrass treatment with CaO, a modified Tilley and Terry (1963) procedure was used to determine IVOMD of bahiagrass hay provided to cattle. Dried and ground (2 mm) samples (0.70 g) from composites of core hay samples taken before feeding were incubated with 50 mL of a 4:1 McDouggall’s buffer:rumin- nal fluid inoculum (McDougall, 1948) in 100-mL plastic centrifuge tubes for 48 h under constant agitation (60 rpm) at 39 °C. Two ruminally cannulated steers consuming bahiagrass hay for at least 14 d were used as ruminal fluid donors. Ruminal fluid was collected from a representative sample of digesta, strained through 4 layers of cheesecloth and placed into warmed (39 °C) bottles until completely full to minimize presence of oxygen. Bottles were capped, placed in thermoses containing warm (39 °C) water and immediately transported to the laboratory, where pH of ruminal fluid was measured before straining through cheesecloth and mixing with the buffer to obtain the inoculum. At all times during inoculum preparation, addition to the tubes, and immediately before capping tubes with a rubber stopper fitted with an 18-G needle, CO₂ was flushed into all containers where ruminal fluid was present to maintain an anaerobic environment. Two tubes per treatment and two blank (without substrate) tubes were incubated in each of three separate replicate days (n = 3/treatment). After the initial 48 h, 6 mL of 20% (v/v) HCl solution was added to the tubes along with 2 mL of a 5% pepsin solution. Tubes were then incubated for an additional 48 h under constant agitation (60 rpm) at 39 °C. With the aid of vacuum, contents of the tubes were filtered through P8 filters (Fisherbrand; Thermo Fisher Scientific Inc.) and liquid was discarded. Wet filters with remaining undigested samples were placed in previously weighed ceramic crucibles and dried at 105 °C in a forced-air oven for 24 h. Crucibles with dry filters and residual samples were placed in a muffle furnace for 6 h at 650 °C before returning to a 105 °C forced-air oven for 24 h prior to recording weight of ashes to calculate IVOMD.

**Statistical Analysis**

For both experiments, all data were analyzed as a randomized complete block design with repeated measures for PUN data. The MIXED procedure of SAS (version 9.4; SAS Inst. Inc., Cary, NC) was used and for performance and PUN data, pasture was considered the experimental unit. In Exp. 1, the model for performance data included the fixed effects of treatment, sex, and their interaction, and the random effects of location and block. For PUN data, pen was considered the subject and the covariance structure chosen was ante-dependence due to unequal spacing between measurements. The model included the fixed effects of treatment, day, and their interaction. Sex, block, location, and pen within treatment were included as random effects, with the latter used to designate the denominator degrees of freedom, which were adjusted using the between-within method. For IVOMD, the average of two tubes per day of incubation was considered the experimental unit and the model included the fixed effect of treatment and the random effect of day of incubation (block). In Exp. 2, the model for performance data included the fixed effects of treatment and sex, and the random effects of location and block. It was not possible to include treatment × sex interaction in the model due to the fact that only two pastures were composed of steers, which were assigned to different treatments; therefore, treatment was repeated only once within pastures of steers. For PUN data, pen was considered the subject and the covariance structure chosen was first order autoregressive based on the smallest Akaike information criterion. The model for PUN was the same as described for Exp.1. In Exp. 1, the following contrast was used for data interpretation: effect of molasses (mean of MOL + CAO vs. DH). Significance was declared at P ≤ 0.05 and tendency considered at 0.05 < P ≤ 0.10 when discussing the effect of molasses.

**RESULTS AND DISCUSSION**

Nutritional composition of bahiagrass hay for all treatments and cottonseed meal from Exp. 2 are presented in Table 1 (Exp. 1) and Table 2 (Exp. 2). In these experiments, all MOL and CAO hay was treated in the same manner in an attempt to bring the DM content of the hay down to 65%. This was likely not accomplished as some of the molasses/water and molasses/water/CAO solution leached out of the bale almost immediately. Furthermore, bales sat uncovered for at least 1 wk prior to feeding
and sampling for nutrient content. It is likely that even more moisture was lost due to evaporation leading to the DM for treated hay being 78 and 83% for Exp. 1 and 2, respectively, when fed to cattle.

Performance of cattle consuming bahiagrass hay treated with CaO and molasses in Exp. 1 is presented in Table 3. No difference among treatments \((P = 0.230)\), between sex \((P = 0.640)\), or treatment \(\times\) sex interaction \((P = 0.551)\) was observed for final BW; however, cattle consuming hay treated with molasses (average of MOL + CAO vs. DH) tended \((P = 0.097)\) to have greater final BW. Consequently, there was no effect of treatment \((P = 0.445)\), sex \((P = 0.324)\), or treatment \(\times\) sex interaction \((P = 0.197)\) on ADG of cattle from d 0 to 56, which had an average loss of BW across treatments of 0.03 kg/d. Moreover, no effect \((P = 0.360)\) of treating hay with molasses was observed on ADG of cattle from d 0 to 56. Similarly, in Exp 2 (Table 4), no difference between treatments \((P = 0.453)\), as well as no effect of sex \((P = 0.670)\), were observed on final BW. Treatment \((P = 0.767)\) nor sex \((P = 0.285)\) had an effect on ADG from d 0 to 56; however, in Exp.2, cattle did not experience weight loss and had an average gain of 0.537 kg/d. Protein supplementation, either as true protein or non-protein nitrogen to poor-quality hay-based diets has been reported to improve performance of beef cattle (Bohnert et al., 2002; Currier et al., 2004; Waters et al., 2015). The main difference between Exp. 1 and Exp. 2 was that cattle in the second experiment were supplemented with cottonseed meal (49% CP) at a rate of 0.3% BW/d and that is a plausible explanation for the absence of weight loss, which

### Table 1. Analyzed nutritional composition of Pensacola bahiagrass (*Paspalum notatum*) hay treated or not with molasses and CaO provided to growing beef cattle (Exp. 1)

| Item\(^3\), % DM | Treatment\(^2\) | CAO |
|-----------------|----------------|-----|
| DM\(^4\), % as fed | DH | MOL | 78.2 ± 1.5 | 77.7 ± 2.3 |
| OM | 94.8 | 94.3 | 91.1 |
| CP | 7.7 | 9.4 | 9.1 |
| NDF | 71.9 | 71.6 | 67.4 |
| ADF | 41.3 | 35.3 | 38.3 |
| Lignin | 3.3 | 2.4 | 3.6 |
| TDN | 62 | 63 | 59 |
| Calcium | 0.39 | 0.50 | 1.62 |

1 Analyzed by a commercial laboratory using a wet chemistry package (Dairy One, Ithaca, NY).
2 DH, untreated dry bahiagrass hay; MOL, bahiagrass hay treated with 10% molasses (DM basis) + water (to 65% DM); CAO, bahiagrass hay treated with 5% CaO (DM basis) + 10% molasses (DM basis) + water (to 65% DM).
3 DM, dry matter; OM, organic matter; CP, crude protein; NDF, neutral detergent fiber; ADF, acid detergent fiber; TDN, total digestible nutrients
4 Analyzed in-house to determine DM of hay prior to cattle feeding.

### Table 2. Analyzed nutritional composition of Pensacola bahiagrass (*Paspalum notatum*) hay treated or not with molasses plus calcium oxide, and cottonseed meal provided to growing beef cattle (Exp. 2)

| Item\(^4\), % DM | Treatment\(^2\) |
|-----------------|----------------|-----|
| NO | MOL | CAO | CSM\(^4\) |
| DM\(^5\), % as fed | 81.5 ± 1.9 | 82.7 ± 1.5 | 88.5 |
| OM | 94.3 | 91.8 | 91.8 |
| CP | 8.3 | 8.4 | 49.1 |
| NDF | 71.8 | 69.1 | 25.4 |
| ADF | 39.2 | 36.6 | 18.7 |
| Lignin | 2.6 | 3.8 | - |
| TDN | 63 | 59 | 69 |
| Calcium | 0.46 | 1.71 | - |

1 Analyzed by a commercial laboratory using a wet chemistry package (Dairy One, Ithaca, NY).
2 MOL, bahiagrass hay treated with 10% molasses (DM basis) + water (to 65% DM); CAO, bahiagrass hay treated with 5% CaO (DM basis) + 10% molasses (DM basis) + water (to 65% DM).
3 DM, dry matter; OM, organic matter; CP, crude protein; NDF, neutral detergent fiber; ADF, acid detergent fiber; TDN, total digestible nutrients
4 CSM, Cottonseed meal; provided at a rate of 0.3% of total pasture BW/d (as fed basis).
5 Analyzed in-house to determine DM of hay prior to cattle feeding.
was observed in the first experiment. Bahiagrass is a warm-season forage that is commonly used for grazing or hay production in Florida and other southeastern states of the United States (Chambliss and Sollenberger, 1991); however, when provided as hay, bahiagrass can be of poor nutritive value, inadequate to support requirements of growing cattle. Thus, additional supplementation of energy, protein, or both is almost always needed (Moore et al., 1991; Hersom et al., 2011). In addition to the idea of masking the taste of CaO, the inclusion of molasses to the hay in both experiments was performed to provide added energy to the hay; however, only in Exp. 2 protein supplementation was provided. As observed in Tables 1 and 2, the total digestible nutrients concentration across treatments was fairly similar, indicating that the addition of molasses may not have provided sufficient added energy in the hay, and potentially explaining the lack in increased ADG in animals consuming hay that contained molasses when compared with those consuming the dry hay. However, final BW of cattle in Exp. 1 tended to be greater when molasses was added to the hay, indicating that greater addition of energy could have been beneficial and potentially reflected on ADG.

Concentrations of PUN in cattle from Exp. 1 and Exp. 2 are presented in Table 5. In both experiments, there was no difference among treatments ($P = 0.768$ and $P = 0.138$; Exp. 1 and Exp. 2, respectively).

| Item $^3$ | Treatment $^2$ | SEM $^4$ | TRT | Sex | TRT × Sex | M $^5$ |
|----------|----------------|---------|-----|-----|-----------|-------|
| Initial BW, kg | 247 | 252 | 258 | 5.1 | 0.319 | 0.825 | 0.213 | 0.185 |
| Final BW, kg | 245 | 255 | 254 | 5.0 | 0.230 | 0.640 | 0.551 | 0.097 |

$^2$Treatment: MOL, bahiagrass hay treated with 10% molasses (DM basis) + water (to 65% DM); CAO, bahiagrass hay treated with 5% CaO (DM basis) + 10% molasses (DM basis) + water (to 65% DM).

$^3$Initial BW and ADG at day 0 and 56 were shrunk while at day 14, 28, and 42 were not.

$^4$Observed significance levels for effects of treatment (TRT) and sex.

$^5$Orthogonal contrast: M = effect of molasses (mean of MOL+CAO vs. DH).

$^1$BW at day 0 and 56 were shrunk while at day 13, 27, and 41 were not.

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Table 4. Performance of growing beef cattle supplemented with cottonseed meal$^1$ and consuming Pensacola bahiagrass ($Paspalum notatum$) hay treated or not with molasses plus calcium oxide (Exp. 2)

| Item $^3$ | Treatment $^1$ | SEM $^4$ | TRT | Sex | TRT × Sex | M $^5$ |
|----------|----------------|---------|-----|-----|-----------|-------|
| Initial BW, kg | 247 | 252 | 258 | 5.1 | 0.319 | 0.825 | 0.213 | 0.185 |
| Final BW, kg | 245 | 255 | 254 | 5.0 | 0.230 | 0.640 | 0.551 | 0.097 |

$^2$Treatment: MOL, bahiagrass hay treated with 10% molasses (DM basis) + water (to 65% DM); CAO, bahiagrass hay treated with 5% CaO (DM basis) + 10% molasses (DM basis) + water (to 65% DM).

$^3$Initial BW and ADG at day 0 and 56 were shrunk while at day 14, 28, and 42 were not.

$^4$Observed significance levels for effects of treatment (TRT), sex, and their interaction (TRT × Sex).

$^5$Orthogonal contrast: M = effect of molasses (mean of MOL+CAO vs. DH).

$^1$BW at day 0 and 56 were shrunk while at day 13, 27, and 41 were not.

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Table 3. Performance of growing beef cattle consuming Pensacola bahiagrass ($Paspalum notatum$) hay treated or not with molasses plus calcium oxide (Exp. 1)

| Item $^1$ | Treatment $^2$ | SEM $^3$ | TRT | Sex | TRT × Sex | M $^5$ |
|----------|----------------|---------|-----|-----|-----------|-------|
| Initial BW, kg | 247 | 252 | 258 | 5.1 | 0.319 | 0.825 | 0.213 | 0.185 |
| Final BW, kg | 245 | 255 | 254 | 5.0 | 0.230 | 0.640 | 0.551 | 0.097 |

$^2$Treatment: MOL, bahiagrass hay treated with 10% molasses (DM basis) + water (to 65% DM); CAO, bahiagrass hay treated with 5% CaO (DM basis) + 10% molasses (DM basis) + water (to 65% DM).

$^3$Initial BW and ADG at day 0 and 56 were shrunk while at day 14, 28, and 42 were not.

$^4$Observed significance levels for effects of treatment (TRT), sex, and their interaction (TRT × Sex).

$^5$Orthogonal contrast: M = effect of molasses (mean of MOL+CAO vs. DH).

$^1$BW, body weight; ADG, average daily gain.

$^2$DH, untreated dry bahiagrass hay; MOL, bahiagrass hay treated with 10% molasses (DM basis) + water (to 65% DM); CAO, bahiagrass hay treated with 5% CaO (DM basis) + 10% molasses (DM basis) + water (to 65% DM).

$^3$Pooled SE of treatment means, $n = 8$ pastures/treatment.

$^4$Observed significance levels for effects of treatment (TRT), sex, and their interaction (TRT × Sex).

$^5$Orthogonal contrast: M = effect of molasses (mean of MOL+CAO vs. DH).

$^1$BW at day 0 and 56 were shrunk while at day 13, 27, and 41 were not.

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Table 2. Performance of growing beef cattle supplemented with cottonseed meal$^1$ and consuming Pensacola bahiagrass ($Paspalum notatum$) hay treated or not with molasses plus calcium oxide (Exp. 2)
respectively) in concentrations of PUN; however, a treatment × day interaction was observed ($P = 0.003$; Figure 1) in Exp. 1. On day 27, cattle consuming treated hay (MOL and CAO), had greater ($P \leq 0.028$) concentrations of PUN when compared with those consuming untreated hay (DH). Any excess of NH$_3$-N in the rumen would be absorbed through the rumen wall into the portal vein and removed by the liver, where it is largely converted to urea (Reynolds and Kristensen, 2008). Urea circulates in the blood and may end up being taken by the kidneys and excreted in the urine or, when dietary protein is not sufficient, can diffuse from the blood back into the rumen, cecum, or into saliva and then back into the rumen. Therefore, PUN concentrations are positively associated with intake of CP, digestible intake protein, and ruminal NH$_3$-N concentrations (Hammond, 1997). Optimal PUN concentrations in growing beef steers were reported to be in the range of 11 to 15 mg/dL to reach maximal rates of gain (Byers and Moxon, 1980). In Exp. 1, PUN concentrations were below this range, which is another indication that protein was not provided at adequate amounts to those animals leading to weight loss; however, in Exp. 2, where cattle were supplemented with cottonseed meal as a protein source, concentrations of PUN are greater and within the range proposed, demonstrating why cattle in Exp. 2 did not experience weight loss, but rather weight gain.

In order to test if treatment with CaO of the bahiagrass hay provided to cattle in Exp. 1 was being effective at improving the digestibility of the forage, and consequently animal performance, IVOMD was performed with samples taken from the hay bales before feeding to cattle, and results are presented in Figure 2. Surprisingly, not only did CaO not improve IVOMD of bahiagrass hay but it actually reduced IVOMD when compared to untreated hay ($P = 0.011$; Error bars represent SEM; $n = 3$/treatment).

### Table 5. Plasma urea nitrogen concentrations of growing beef cattle consuming Pensacola bahiagrass (Paspalum notatum) hay treated or not with molasses plus CaO (Exp. 1 and Exp. 2)

| Item | Treatment$^1$ | TRT | day | TRT × day |
|------|--------------|-----|-----|----------|
| PUN$^2$, mg/dL | DH | MOL | CAO | SEM$^4$ | TRT | day | TRT × day |
| Exp. 1 | 9.70 | 10.16 | 9.89 | 0.359 | 0.768 | <0.001 | 0.003 |
| Exp. 2$^3$ | - | 11.97 | 11.10 | 0.483 | 0.138 | <0.001 | 0.681 |

$^1$DH, untreated dry bahiagrass hay; MOL, bahiagrass hay treated with 10% molasses (DM basis) + water (to 65% DM); CAO, bahiagrass hay treated with 5% CaO (DM basis) + 10% molasses (DM basis) + water (to 65% DM).

$^2$PUN, plasma urea nitrogen

$^3$In Exp. 2 only MOL and CAO were provided as treatments and cattle were provided cottonseed meal at a rate of 0.3% of total pasture BW/d (as fed basis).

$^4$Pooled SE of treatment means, $n = 8$ pastures/treatment.

$^5$Observed significance levels for effects of treatment (TRT), day, and their interaction (TRT × day).

![Figure 1. Plasma urea nitrogen (PUN) concentrations of growing beef cattle consuming Pensacola bahiagrass (Paspalum notatum) hay treated or not with molasses plus CaO (Exp. 1). A treatment × day interaction was observed ($P = 0.003$); DH, untreated dry bahiagrass hay; MOL, bahiagrass hay treated with 10% molasses (DM basis) + water (to 65% DM); CAO, bahiagrass hay treated with 5% CaO (DM basis) + 10% molasses (DM basis) + water (to 65% DM); Error bars represent the SEM for treatment × day interaction; *$P \leq 0.028$.](image1)

![Figure 2. In vitro organic matter digestibility (IVOMD) of Pensacola bahiagrass (Paspalum notatum) hay provided to beef cattle in Exp. 1; DH, untreated dry bahiagrass hay; MOL, bahiagrass hay treated with 10% molasses (DM basis) + water (to 65% DM); CAO, bahiagrass hay treated with 5% CaO (DM basis) + 10% molasses (DM basis) + water (to 65% DM). $^a,b$Means with different superscripts differ; $P = 0.011$; Error bars represent SEM; $n = 3$/treatment.](image2)
was observed between hay treated with molasses (MOL) only or with molasses and CaO (CAO).

The results obtained in vitro can further explain the lack of increased performance that was expected in cattle consuming bahiagrass hay treated with CaO when compared with nontreated hay and indicate that the method of treatment may not have been the best approach to achieve the results desired. Different from previous experiments performed by our research group (F.M. Ciriaco, unpublished data), the method of treatment in this experiment did not involve mixing of the forage with the CaO and addition of water but, rather, soaking of the hay bale instead, by pouring a mixture of water and CaO on the flat side of the round bale. Perhaps there was not a proper contact of the CaO with the forage fiber, preventing the disruption of the bonds between lignin and the polysaccharides hemicellulose and cellulose by the hydrated CaO (Klopfenstein, 1978). Moreover, it has been suggested that particle size is important for the alkali treatment to be effective, where smaller particles would respond better to treatment than larger ones (Shreck et al., 2012; Euken et al., 2013; Peterson et al., 2015b). In this experiment, the whole round bale was soaked with the mixture and in previous experiments the hay was chopped before treatment, promoting greater surface area for adherence of the powder and reaction to occur. The method of treatment in the current experiment was chosen to reflect closer conditions that a producer would be able to implement in real-life production systems. Therefore, bahiagrass hay treated with CaO and molasses using the approach described herein failed to improve beef cattle performance and further investigation is needed to evaluate different methods of treatment that can be easily implemented by end users.

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