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Nutritive value, fermentation characteristics, and in situ disappearance kinetics of sorghum silage treated with inoculants

M. E. Thomas,* J. L. Foster,†[1] K. C. McCuistion,‡ L. A. Redmon,* and R. W. Jessup*
*Department of Soil and Crop Sciences, Texas A&M University, College Station 77843
†Texas A&M AgriLife Research, Texas A&M University System, Beeville 78410
‡King Ranch Institute for Ranch Management, Texas A&M University-Kingsville 78363

ABSTRACT

Fibrolytic enzymes and microbial inoculants have the potential to improve the value of sorghum feedstuff and feedstock. An experiment was conducted to determine nutritive value, ensiling characteristics, and in situ disappearance kinetics of 4 sorghum (S*orghum bicolor* L.) silage varieties: Dairy Master BMR (DBMR; brown midrib; Richardson Seed, Vega, TX), PS 747 (PS; photoperiod sensitive; Pogue Seed, Kenedy, TX), Silo 700D (S700D; conventional forage type; Richardson Seed), and MMR 381/73 (MMR; conventional forage type; Richardson Seed) pretreated with fibrolytic enzyme (xylanase plus cellulase, XC; 50:50 mixture of Cellulase Plus and Xylanase Plus; Dyadic, Juniper, FL) or microbial [Promote ASB (*Lactobacillus buchneri* and *Lactobacillus plantarum*); Cargill Animal Nutrition, Indianapolis, IN; PRO] inoculants. The greatest yield was for cultivar PS and the least for MMR. Neutral detergent fiber (NDF) concentration was least for XC-treated silage, and acid detergent fiber (ADF) concentration was least for XC- and PRO-treated silage. When silage was treated with XC, concentrations of NDF concentrations decreased, on average, 4.81% across all cultivars and ADF concentrations decreased, on average, 3.23% in all cultivars except MMR. Inoculant PRO reduced the NDF concentration of DBMR by 6.47%. The ADF concentrations of DBMR and PS treated with PRO were decreased by 3.25%. Treating sorghum silage with XC or PRO reduced the NDF and ADF fractions, which increased cell wall degradability. In vitro true digestibility was greatest for PRO-treated DBMR, whereas acid detergent lignin was least for PRO-treated DBMR. Aerobic stability was not improved by PRO; however, aerobic stability of XC-treated MMR was 63 h greater than that of the control. Acetate concentrations were greatest for XC-treated MMR, which explains the 63-h improvement in aerobic stability due to the inhibition of fungi. However, inoculant PRO did not improve yeast and mold counts or aerobic stability of sorghum silage compared with the control, which may be due to the lesser acetate concentrations, especially of PRO-treated S700D silage. Generally, in situ disappearance kinetics were improved with the application of XC and PRO, and XC had the greatest effect on silage with greater NDF and ADF concentrations.

Key words: sorghum, silage, fibrolytic enzyme, microbial inoculant

INTRODUCTION

Sorghum silage can be fed to livestock or used as biomass for biofuel production. In 2010, 13,102 ha were harvested for silage production in Texas (USDA, 2011). Sorghum is well adapted to the climate, has a high yield, and is drought tolerant, making it an excellent crop to meet the grain or forage needs of the livestock industry (Prostko et al., 1998). However, acceptance of sorghum silage for livestock feed has been limited because of its greater ADF and ADL levels compared with corn silage (Prostko et al., 1998). The greater fiber levels found in sorghum reduce forage digestibility and may compromise milk production (Prostko et al., 1998). Bolsen et al. (1989) reported that grain sorghum silage can be substituted for corn silage in mid-lactation dairy cattle diets with no adverse effects on milk production, whereas others have reported that silage from brown midrib (**BMR**) sorghum supports milk production similar to that of corn silages (Lusk et al., 1984; Grant et al., 1995; Oliver et al., 2004).

During the ensiling process, DM is lost if fermentation does not occur immediately and aerobic stability is not maintained during storage and feedout (McDonald et al., 1991; Jones, 2012). Therefore, limitations to sorghum silage use include storage constraints and fiber degradation, and both may be improved by the application of fibrolytic enzyme or bacterial inoculant, thereby, increasing the value of sorghum silage. Treating silage with fibrolytic enzymes breaks bonds between hemicelluloses and lignin so that sugars can be extracted from

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[1]Corresponding author: jlfoster@ag.tamu.edu

hemicelluloses (Han et al., 2007). Elwakeel et al. (2007) found that the in vitro DM digestibility of 4 fibrous dairy feedstuffs was improved by addition of a fibrolytic enzyme mixture containing β-glucanase, xylanase, and cellulase. Bacterial inoculants containing lactic acid bacteria (**LAB**) increase aerobic stability by inhibiting aerobic spoilage (Kung and Charley, 2010). Inoculation of biofuel crops with biological silage additives and ensiling prolongs crop storage and improves methane yields up to 11% (Herrmann et al., 2011).

Forage sorghum has been bred to favor improved nutritive value and yield. Photoperiod-sensitive (**PPS**) varieties have high yields and use water efficiently; however, their reduced digestibility and greater fiber than conventional forage sorghum cultivars limits their broad application (McCollum et al., 2012). Increased fiber concentrations and reduced digestibility of PPS silage may reduce its feedstock and feedstuff value because fiber degradation is one of the major limitations to value. However, Murray et al. (2008) suggested that yield traits be selected over composition traits for maximizing energy yield of sorghum biomass. This suggestion is similar to the conclusion of McCuistion et al. (2011) that PPS varieties fed more cattle than varieties with greater nutritive value. Varieties selected for BMR traits have less ADL and may be 10 to 30% more digestible; however, DM yield may be 15 to 20% less and lodge and bend more easily (Ball et al., 2007).

Despite the large acreage of sorghum grown in the United States, limited information is available on the ensiling characteristics, nutritive value, and in situ kinetics of sorghum silage pretreated with fibrolytic enzymes or bacterial inoculants. The lack of information is especially apparent regarding genetically improved PPS and BMR types. Thus, the goal of this study was to determine nutritive value, fermentation characteristics, aerobic stability, and in situ ruminal disappearance kinetics of conventional, PPS, and BMR sorghum silages pretreated with fibrolytic enzymes (cellulase:xylanase) or bacterial inoculant.

MATERIALS AND METHODS

Forage Production and Ensiling

Sorghum cultivars Dairy Master BMR (**DBMR**; brown midrib; Richardson Seed, Vega, TX), PS 747 (**PS**; photoperiod sensitive; Pogue Seed, Kenedy, TX), Silo 700D (**S700D**; conventional forage type; Richardson Seed), and MMR 381/73 (**MMR**; conventional forage type; Richardson Seed) were grown at the Texas A&M AgriLife Research Station in Beeville (28°N, 98°W) and the Texas A&M University Agriculture Research Farm in College Station (30°N, 96°W), Texas. At planting, sorghum was sprayed with a tank mix of 0.575 L/ha of atrazine + 0.339 L/ha of metolachlor, and no fertilizer was applied. Sorghum was harvested during the mid-dough stage, at which time 4 random height measurements were recorded; 7.3 m of sorghum was cut from the 2 center rows to a 10-cm stubble height, and a subsample (3.66 m row length) was weighed to calculate yield. Material was chopped into at least 13-mm particle size using a chopper shredder (Earthquake, Cumberland, WI). A 1-kg subsample of forage was dried at 65°C until weight loss ceased. Samples were ground to 4 mm and subsamples used for nutritive value analysis of pre-ensiled sorghum were ground to pass through a 2-mm screen in a Wiley mill (Arthur H. Thomas Company, Philadelphia, PA).

Chopped sorghum (5 kg) was sprayed with 200 mL of distilled water (control), 1.34 mL of fibrolytic enzymes (**XC**), or 16.5 mg of bacterial inoculant (**PRO**; Promote ASB, *Lactobacillus buchneri*, *Pediococcus acidilactici*, *Pediococcus pentosaceous*, *Lactobacillus plantarum*, *Enterococcus faecium*; Cargill Animal Nutrition, Indianapolis, IN) mixed in 200 mL of distilled water. Bacterial inoculant PRO is marketed as a water-soluble forage inoculant and instructions for its use indicate that is to be mixed with water before spray application. Enzyme activity was approximately 35,000 units of XC/g for XC-treated silage and approximately 100,000 cfu/g for PRO-treated silage. The fibrolytic enzyme mixture was a 50:50 mixture of Cellulase Plus (Dyadic, Juniper, FL), which is a liquid acid cellulose enzyme produced by the fermentation of non-genetically modified *Trichoderma longibrachiatum* and Xylanase Plus (Dyadic), which is a liquid acid-neutral endo-1,4-β-D-xylanase produced by the fermentation of non-genetically modified *T. longibrachiatum*. Additional enzyme activities in the XC product included β-glucanase, pectinase, mannanase, xyloglucanase, laminarase, β-glucosidase, β-xylosidase, α-L-arabinofuranosidase, amylase, and protease. Inoculant type and dose were determined based on results of application to corn silage in previous studies of other research groups and the label-recommended application rate. Silage was hand mixed and packed into mini-silos, which were 17.6-L containers with lids and were lined with 38.1 × 22.9 × 61 cm polyethylene bags and sealed for at least 120 d.

Laboratory Analyses

After 120 d, silos were opened and 4 separate subsamples were taken. The first subsample was dried at 65°C and ground to pass through a 4-mm screen and then a subsample ground to pass through a 2-mm screen in a Wiley mill for nutritive value analysis. The second silage subsample was sent to Dairy One (Ithaca, NY)