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Effect of feeding warm-season annuals with orchardgrass on ruminal fermentation and methane output in continuous culture

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ABSTRACT

A 4-unit, dual-flow continuous culture fermentor system was used to assess nutrient digestibility, volatile fatty acids (VFA) production, bacterial protein synthesis, and methane (CH_4) output of warm-season annual grasses. Treatments were randomly assigned to fermentors in a 4 × 4 Latin square design using 7 d for adaptation to treatment and 3 d for sample collection. Treatments were (1) 100% orchardgrass (*Dactylis glomerata* L.; ORD); (2) 50% orchardgrass + 50% Japanese millet [*Echinochloa esculenta* (A. Braun) H. Scholz; MIL]; (3) 50% orchardgrass + 50% brown midrib sorghum × sudangrass (*Sorghum bicolor* L. Moench × *S. bicolor* var. *sudanense*; SSG]; or (4) 50% orchardgrass + 25% millet + 25% sorghum × sudangrass (MIX). Fermentors were fed 60 g of dry matter (DM)/d in equal portions of herbage 4 times daily (0730, 1030, 1400, and 1900 h). To replicate a typical 12-h pasture rotation, fermentors were fed the orchardgrass at 0730 and 1030 h and the individual treatment herbage (orchardgrass, Japanese millet, sorghum × sudangrass, or 50:50 Japanese millet and sorghum × sudangrass) at 1400 and 1900 h. Gas samples for CH_4 analysis were collected 6 times daily at 0725, 0900, 1000, 1355, 1530, and 1630 h. Fermentor pH was determined at the time of feeding, and fermentor effluent samples for NH_3-N and VFA analyses were taken daily at 1030 h on d 8, 9, and 10. Samples were also analyzed for DM, organic matter (OM), crude protein, and fiber fractions to determine nutrient digestibilities. Bacterial efficiency was estimated by dividing bacterial N by truly digested OM. True DM and OM digestibilities and pH were not different among treatments. Apparent OM digestibility was greater in ORD than in MIL and SSG. The concentration of propionate was greater in ORD than in SSG and MIX, and that of butyrate was greatest in ORD and MIL. Methane output was greatest in MIL, intermediate in ORD, and lowest in SSG and MIX. Nitrogen intake did not differ across treatments, whereas bacterial N efficiency per kilogram of truly digestible OM was greatest in MIL, intermediate in SSG and MIX, and lowest in ORD. True crude protein digestibility was greater in ORD versus MIL, and ORD had lower total N, non-NH_3-N, bacterial N, and dietary N in effluent flows than MIL. Overall, we detected little difference in true nutrient digestibility; however, SSG and MIX provided the lowest acetate to propionate ratio and lower CH_4 output than MIL and ORD. Thus, improved warm-season annual pastures (i.e., brown midrib sorghum × sudangrass) could provide a reasonable alternative to orchardgrass pastures during the summer months when such perennial cool-season grass species have greatly reduced productivity.
Key words: continuous culture, ruminal fermentation, warm-season annual

INTRODUCTION

Perennial cool-season grasses provide high-quality forage for pasture-based dairy systems in the temperate regions of the United States throughout the spring and fall grazing seasons. However, forage production and quality decline markedly during the hot summer months (July and August), an occurrence frequently referred to as the “summer forage slump.” Winsten et al. (2010) reported that, of 987 dairy farms surveyed across the northeastern United States, 13% used management-intensive rotational grazing and 80% of farms used a combination of low-intensity grazing and traditional confinement systems. According to Stiglbauer et al. (2013), 85 and 95% of the conventional pasture-based and organic-certified dairies, respectively, used management-intensive rotational grazing across New York, Wisconsin, and Oregon. With the number of pasture-based dairies expected to increase as a result

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of increasing demand for grass-fed and organic milk (Pereira et al., 2013), a requirement for pasture-based diets with some milk processors (e.g., certified organic labels through USDA-National Organic Program or labels through individual processors), and some climate models predicting warmer, drier summers for temperate regions during the next century (Wolfe et al., 2008), evaluation of heat- and drought-tolerant warm-season forages that can support profitable milk production in pasture-based dairy cattle is paramount.

Warm-season annuals such as sorghum, sudangrass, sorghum × sudangrass hybrids, and millets have been promoted as highly productive forages, but are considered to be highly lignified and have low leaf-to-stem ratios, resulting in lower-quality forage and reduced digestibility compared with perennial cool-season forages (Cowan and Lowe, 1998). Research in the northeastern United States reported that brown midrib (**BMR**) sorghum × sudangrass yielded 7,297 kg (DM)/ha and contained 12.9% CP and 61.7% NDF, with the NDF reported to be 77.5% digestible (Ketterings et al., 2005). Using a prediction model (Milk2000; http://www.uwex edu/ces/forage/pubs/milk2000.xls), the estimated milk production was 1,552 kg of milk/Mg of forage DM and 11,301 kg of milk/ha. However, this model does not consider air temperature, which can have a negative effect on DMI and milk production when temperatures exceed 20°C (NRC, 2001). Fontaneli et al. (2001) observed that intensively managed warm-season annuals grown in a subtropical climate were of sufficient yield and quality (5.7 Mg of DM/ha, 18.3% CP, and 61.6% in vitro OM digestibility to meet the nutritional demands of lactating dairy cows producing 20 kg of milk/d; NRC, 2001). Fontaneli et al. (2001) also stated that warm-season annuals would significantly contribute to the development of a year-round, grazing dairy system. However, there is currently no literature available on the performance of lactating dairy cows consuming warm-season annuals compared with perennial, cool-season forage.

Even though it has been considered standard practice to include warm-season annuals in the forage program of pasture-based dairy farms in temperate regions such as the northeastern United States since the 1960s (Clark et al., 1965), only limited information is available on the digestibility and animal production potential of warm-season annuals when used in the diet of lactating dairy cows. Furthermore, new varieties (e.g., BMR) have been developed that could prove to be of superior nutritional quality compared with older varieties of warm-season annuals (Ketterings et al., 2005). Therefore, the objective of the current study was to determine the effects of Japanese millet, BMR sorghum × sudangrass, and a mixture of both on nutrient digestibility, VFA production, bacterial protein synthesis and methane (CH_4) output in continuous culture compared with a typical, cool-season herbage (i.e., orchardgrass). We hypothesized that inclusion of the warm-season annual forages will provide greater digestible OM compared with orchardgrass alone, resulting in improved ruminal fermentation and decreased CH_4 production per unit of OM digested.

MATERIALS AND METHODS

Site, Experimental Design, and Herbage Treatments

The study was conducted at the USDA-Agricultural Research Service Pasture Systems and Watershed Management Research Unit (University Park, PA) from February to April 2015. On June 16, 2014, FSG 208 BMR (Seedway LLC, Hall, NY) hybrid sorghum × sudangrass (*Sorghum bicolor* L. Moench × *S. bicolor* var. *sudanense*) and Japanese millet [*Echinochloa esculenta* (A. Braun) H. Scholz] were planted into a prepared seedbed using a no-till drill (HEGE 1000; Wintersteiger AG, Waldenburg, Germany). Plots were fertilized with 46 kg of N/ha in a split-application using ammonium sulfate; P and K were applied to plots according to soil test results. Plots were harvested twice during the growing season (July 17 and September 23, 2014), when herbage height was within the optimal range for grazing (45 to 75 cm; Hodgson et al., 1977). Orchardgrass (*Dactylis glomerata* L.) was harvested in the morning of July 2 and September 23, 2014, from a 1-yr-old pure stand. Orchardgrass was harvested in a vegetative stage of growth, typical of high-quality pastures used for grazing in temperate regions of the United States (25 to 30 cm tall). A plot harvester (HEGE 212; Wintersteiger AG; 1.5-m-wide swath), set to a 10-cm stubble height was used to harvest all plots. Within 30 min of harvest, herbage was placed in cloth bags and frozen (−4°C) until being freeze-dried (Ultra 35 Super ES; Virtis Co. Inc., Gardiner, NY). Freeze-dried herbage was ground to pass through a 2-mm sieve (Wiley mill; Thomson Scientific Inc., Philadelphia, PA) to be used as feed for the fermentors. Although we recognize that freeze-dried forages are not nutritionally identical to fresh forages, the herbage needed to be preserved and ground for use in this experiment, and Jones and Bailey (1972) reported that oven-drying forages could denature protein in plant material and depress digestibility.

Total DM fed to all fermentors was maintained at a constant 60 g/d for the duration of each period. Treatments were as follows: (1) 100% orchardgrass (**ORD**); (2) 50% orchardgrass + 50% Japanese millet (**MIL**); (3) 50% orchardgrass + 50% sorghum × sudangrass (**SSG**); or (4) 50% orchardgrass + 25% Japanese millet