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Effect of sprouted barley grain supplementation of an herbage-based or haylage-based diet on ruminal fermentation and methane output in continuous culture[1]

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ABSTRACT

A 4-unit dual-flow continuous-culture fermentor system was used to assess the effect of supplementing 7-d sprouted barley (SB) or barley grain (BG) with an herbage-based or haylage-based diet on nutrient digestibility, volatile fatty acid (VFA) profiles, bacterial protein synthesis, and methane (CH_4) output. Treatments were randomly assigned to fermentors in a 4 × 4 Latin square design with a 2 × 2 factorial arrangement using 7 d for diet adaptation and 3 d for sample collection. Experimental diets were (1) 55.5 g of herbage dry matter (DM) + 4.5 g of SB DM, (2) 56.0 g of herbage DM + 4.0 g of BG DM, (3) 55.5 g of haylage DM + 4.5 g of SB DM, and (4) 56.0 g of haylage DM + 4.0 g of BG DM. Forages were fed at 0730, 1030, 1400, and 1900 h, whereas SB and BG were fed at 0730 and 1400 h. Gas samples for CH_4 analysis were collected at 0725, 0900, 1000, 1355, 1530, and 1630 h on d 8, 9, and 10. Fluid samples were taken once daily on d 8, 9, and 10 for pH measurements and for ammonia-N and VFA analysis and analyzed for DM, organic matter, crude protein, neutral detergent fiber, and acid detergent fiber for determination of nutrient digestibilities and estimation of bacterial protein synthesis. Orthogonal contrasts were used to compare the effect of forage source (haylage vs. herbage), supplement (BG vs. SB), and the forage × supplement interaction. Apparent and true DM and organic matter digestibilities as well as apparent crude protein digestibility were not affected by forage source. However, true DM digestibility was greatest for diets supplemented with SB. Apparent neutral and acid detergent fiber digestibilities of herbage-based diets were higher than haylage-based diets but fiber digestibility was not affected by supplement. Diets supplemented with SB had higher mean and minimum pH than BG; however, maximum pH was not affected by diet. Supplementation with BG produced a greater concentration of total VFA compared with diets supplemented with SB. Haylage-based diets produced greater CH_4 output compared with herbage-based diets but supplementation did not affect CH_4 output. Efficiency of bacterial protein synthesis was greater for herbage-based diets compared with haylage-based diets, with no effect of supplementation. Overall, supplementation with SB marginally increased true DM digestibility of herbage- and haylage-based diets but did not affect fiber and crude protein digestibilities, CH_4 output, and bacterial efficiency, compared with BG.

Key words: continuous culture fermentation, grazing, sprouted barley

INTRODUCTION

Sprouted grain has been suggested as a method to produce fresh forage in areas where water shortages and seasonality of forages are common challenges for livestock producers (Rodríguez-Muela et al., 2005; Rodríguez, 2012). Sprouted barley (**SB**) is barley grain (**BG**) that has been soaked in water, placed in trays, and allowed to germinate and sprout for 6 to 8 d (Peer and Leeson, 1985; Dung et al., 2010a,b; Fazaeli et al., 2012). The resulting interwoven mat of roots and green shoots are then fed to livestock. Sprouting barley seed produces a significant increase in fresh weight during the sprouting duration, as germination converts starch, protein, and lipids to their basic forms (e.g., starch changes to sugar; Chung et al., 1989; Dung et al., 2010a,b; Fazaeli et al., 2012). Barley grain can be produced in many regions of the United States and the price of this small grain has remained relatively affordable ($0.26/kg in 2011; USDA-ERS, 2011). Barley has been found to produce greater fresh and DM yields when sprouted hydroponically compared with other cereal grains such as wheat (Al-Karaki and Al-Hashimi, 2012). Feeding sprouted grains is an old technology that is gaining renewed interest, particularly in parts of the country such as the Northeast, where producing high-quality forage has recently become more challeng-

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ing due to changing weather patterns (drought or high-intensity rainfall events) and a decline in availability of arable land (Nickerson et al., 2011; Griffin et al., 2014). Furthermore, increasing costs of corn, a desire for some grazing dairies to move away from grain supplements, and an interest in an alternative solution to producing high-quality fresh forage year-round have been cited as reasons for dairy farmers to consider using sprouting technology. Finally, manufacturers marketing various sizes of hydroponic livestock feed growth systems have helped lead the reemergence in producer interest with trade-show appearances and internet videos claiming exceptional forage yields and increased animal health and performance. Producer testimonials featured in industry publications have cited anecdotal observations of improved animal health (lower SCC and improved reproductive success, immune response, and milk yield and quality; Anderson, 2009; Sergeant, 2012). However, little scientific evidence is currently available to support claims made by manufacturers of hydroponic livestock feed systems and to justify farmers' adoption of sprouting technology.

Previous research regarding the feeding value of SB and other sprouted grains to ruminants indicates that the benefits of sprouting may be negated by the total DM loss from sprouting coupled with no significant improvement in nutrient concentrations or digestibility (Dung et al., 2010a). Several studies have suggested that feeding sprouted grains may only increase performance in animals not receiving adequate protein, energy, or minerals (Thomas and Reddy, 1962; Sneath and McIntosh, 2003), or that the readily available nutrients in SB may stimulate enhanced utilization of poor-quality forages (Tudor et al., 2003). Currently, no information is available regarding the feeding value of SB with high-quality forages, such as the conserved forages and pastures found on well-managed grazing dairy farms. Therefore, the objective of this study was to use in vitro continuous-culture fermentation to evaluate the effects of supplementing SB or BG with an herbage-based or conserved forage diet on ruminal fermentation, nutrient digestibility, bacterial protein synthesis, and CH_4 output. We hypothesized that supplementing herbage- and haylage-based diets with SB will increase nutrient digestibility of these diets and reduce CH_4 output compared with BG in continuous culture.

MATERIALS AND METHODS

Site, Experimental Design, and Diets

This study was conducted at the USDA-Agricultural Research Service Pasture Systems and Watershed Management Research Unit (University Park, PA) from January to March 2013. Forages were harvested from a mixed-species pasture containing perennial ryegrass (*Lolium perenne* L.), Kentucky bluegrass (*Poa pratensis* L.), white clover (*Trifolium repens* L.), and red clover (*Trifolium pretense* L.) in Shippensburg (Pennsylvania) and a tall fescue (*Festuca arundinacea*) pasture in Kinzers (Pennsylvania) on October 4 and 5, 2012, respectively. At the time of harvest, all forage was at the vegetative stage of development and was composited at a ratio of 2:1 DM for the clover/grass mixture and tall fescue, respectively, to represent typical cool-season grass/legume pastures found on grazing dairy farms in Pennsylvania. Haylage was obtained from a storage bay from a dairy farm in Kinzers and comprised an alfalfa (*Medicago sativa* L.) and tall fescue mix. Herbage and haylage were stored in freezers at −20°C until freeze-drying (Ultra 35 Super ES; VirTis Co. Inc., Gardiner, NY).

The barley (*Hordeum vulgare* L.) seed used for the BG supplement and to grow the SB was a winter hulless variety purchased from Lakeview Organic Grain LLC (Penn Yan, NY). Clean BG seeds (130 g as fed) were soaked for 6 h in distilled water and spread in sprouting containers (8 × 14 cm) to obtain a depth of 1.9 cm. Sprouted barley was grown for 7 d in a growth chamber (model no. PGR16; Conviron, Winnipeg, MB, Canada; 81 × 183 × 107 cm) equipped with automatic sprayer irrigation. The automatic watering system was controlled by an in-line commercial timing device (Orbit model no. 27729; Orbit Irrigation Products Inc., Bountiful, UT) set to deliver water through a fine misting nozzle for 1 min every 6 h. Total water delivered per watering was 1.9 L and came from the domestic cold water supply and contained <0.5 mg/L residual Cl. Holes drilled in the bottom of the sprouting containers allowed for drainage between watering. The temperature inside the chamber was controlled at 21°C with 50% relative humidity. Light from incandescent, metal halide, and sodium light sources provided 12 h of daily light (0400 to 1600 h). To ensure a constant supply of fresh 7-d SB, new containers were seeded daily. Freeze-dried herbage and haylage, as well as the BG were ground to pass through a 2-mm screen (Wiley mill; Thomson Scientific Inc., Philadelphia, PA) to be used as feed for the fermentors.

A separate set of 6 trays of SB were grown simultaneously using the same protocol to determine fresh weight gain and DM loss with each day of sprouting. Each day, 1 tray was removed from the growth chamber and the contents emptied onto a tray with a paper towel and allowed to drain excess water for 30 min. The sprouted seeds were then weighed to determine fresh weight and placed in a forced-air oven for 48 h at 60°C to determine DM content.