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Effect of ensiling time on fermentation profile and ruminal in vitro starch digestibility in rehydrated corn with or without varied concentrations of wet brewers grains

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ABSTRACT

The objective of this study was to evaluate the effect of rehydrating and ensiling dry ground corn (DGC) with varying concentrations of wet brewers grain (WBG) on fermentation profile and ruminal in vitro starch digestibility (ivSD; 7-h incubations on dried and 4-mm ground samples). Samples of DGC and WBG were weighed separately and mixed into 100% WBG (WBG); mixture of DGC and WBG targeting 60 (RC60), 65 (RC65), or 70% (RC70) of dry matter (DM); and DGC rehydrated with distilled water targeting for 70% of DM (REH). Samples were ensiled in vacuum-sealed bags and allowed to ferment for 0, 1, 3, 7, 14, and 28 d. The experiment consisted of 30 treatments (5 mixtures of DGC and WGB × 6 ensiling time points) and 120 mini-silos (4 silos per treatment). All samples were analyzed for fermentation profile and water-soluble carbohydrates. Except for WBG, samples from 0 and 28 d were analyzed for ivSD. Content of DM was greater for REH (70.0%), followed by RC70 (69.2%), RC65 (63.9%), RC60 (58.4%), and WBG (17.5%) on d 0, with a slight decrease (1 to 2 percentage units) observed for all treatments until 28 d. Measurements of pH were highest for REH (6.19) and lowest for WBG (4.68) on 0 d, but all other treatments were lower than WBG on 14 and 28 d (3.83 vs. 4.14, on average). Except for WBG, all treatments had a gradual increase in lactic acid concentration from 0 to 28 d. In contrast, butyric acid gradually increased from 0 (0.25%) to 28 d (2.16% of DM) in WBG but not the other treatments. Fermentation patterns were related to water-soluble carbohydrates concentration, which was greater for all treatments except WBG from 0 (1.41% on average vs. 0.38% of DM, respectively) to 28 d (0.37% on average vs. 0.19% of DM, respectively). Except for RC60, greater ivSD was observed for all treatments on 28 than 0 d, but magnitude of the difference was greater for REH and RC70 (14.5 percentage units on average). Rehydration and ensiling of DGC with WBG resulted in adequate fermentation and enhanced starch digestibility.
Key words: rehydrated corn, wet brewers grain, starch digestibility, ensiling

INTRODUCTION

Starch is the main energy source in corn grain, the most predominant feed energy source in the United States dairy industry (USDA-ERS, 2016), and comprises approximately 70% (DM basis) of its nutrient composition. Greater starch digestibility is consistently associated with enhanced milk yield and feed efficiency by lactating dairy cows (Firkins et al., 2001; Ferraretto et al., 2013); thus, improvements in the use of starch by lactating dairy cows is of much interest to dairy farmers and their nutritionists.

Numerous factors influence starch digestibility in corn, including particle size, grain processing, and storage methods (Firkins et al., 2001; Ferraretto et al., 2013). During the ensiling process, zein protein subunits that crosslink starch granules undergo proteolysis (Hoffman et al., 2011), which explains greater ruminal and total-tract starch digestibility when cows are fed high-moisture corn (**HMC**) in comparison with dry ground corn (**DGC**; Firkins et al., 2001; Ferraretto et al., 2013). In certain areas (i.e., Brazil), however, the interval for HMC harvesting is narrow, as it coincides with a period of excessive rainfall, which could delay harvesting and, hence, impair fermentation and starch digestibility (Goodrich et al., 1975; Ferraretto et al., 2014). Dry ground corn can be rehydrated to achieve moisture levels that suffice an ensiling process (Rezende et al., 2014). Rehydration and ensiling of DGC was previously reported to enhance ruminal in vitro starch digestibility (**ivSD**; Ferraretto et al., 2015) and was suggested as an alternative for dairy producers in those

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areas where weather conditions challenge optimal harvest and storage of HMC. A recent study by Arcari et al. (2016) reported enhanced total-tract starch digestibility and milk production when DGC was replaced with rehydrated and ensiled corn in dairy cattle diets.

Although water is typically used in the process of corn rehydration, other products with high-moisture concentration could be used (Rezende et al., 2014). Wet brewers grains (**WBG**) is a by-product of the brewing process and is widely available in Florida. The main limiting factor for effective use of WBG is its low DM content, which hinders storage and preservation of this residue (Souza et al., 2012). Although ensiling could be an alternative for the storage of WBG (Souza et al., 2012), sugars are removed from the grain during the malting process, which sometimes could result in inadequate amounts of sugars for silage fermentation (Westendorf and Wohlt, 2002). Perhaps WBG could be used as a source of moisture for rehydration of DGC resulting in adequate moisture for ensiling, and thereby result in improved starch digestibility. On the other hand, corn would provide adequate substrate concentration for silage fermentation and improve storage of WBG.

Therefore, our experimental objectives were to evaluate the effect of ensiling time on fermentation profile and ivSD of DGC rehydrated and ensiled without or with 3 concentrations of WBG. We hypothesized that rehydration of DGC with WBG followed by ensiling would result in fermentation patterns similar to rehydration with distilled water. Furthermore, enhanced ivSD would be achieved with rehydration and ensiling regardless of moisture source.

MATERIALS AND METHODS

Forty kilograms of DGC (finely ground, mean particle size = 649 μm) and 30 kg of WBG (mean particle size = 687 μm) were obtained from the University of Florida Dairy Research Unit (Gainesville) in September 2016. Samples of DGC and WBG were homogenized, weighed out separately, and thoroughly mixed into 100% WBG (**WBG**); mixture of DGC and WBG targeting 60 (**RC60**), 65 (**RC65**), or 70% (**RC70**) of DM; and DGC rehydrated with distilled water targeting for 70% of DM (**REH**). For each treatment, mixtures for each silo were independently prepared by hand-mixing, placed in nylon-polyethylene standard barrier vacuum pouches (3.5-mil thickness, 25.4 × 35.6 cm; Doug Care Equipment Inc., Springville, CA) containing 500 g of as-fed mixture each, vacuum heat-sealed using an external clamp vacuum machine (Bestvac; distributed by Doug Care Equipment Inc.), and ensiled for 0, 1, 3, 7, 14, and 28 d. Thus, the experiment consisted of 30 treatments (5 mixtures × 6 ensiling time points) and 120 mini-silos (quadruplicates per treatment). Mini-silos were stored at room temperature (approximately 22°C) in the dark until reaching the targeted ensiling time. After the ensiling time was reached the bags were immediately frozen and stored at −20°C to stop fermentation until being processed for analysis. All samples were frozen for at least 7 d to ensure protocol similarity among all samples.

A composite sample of each treatment was prepared using 0-d samples for nutrient characterization. Composite samples were sent to Dairyland Laboratories Inc. (Arcadia, WI) and analyzed for ash (method 942.05, AOAC International, 2012), CP (method 990.03, AOAC International, 2012), ether extract (method 920.39, AOAC International, 2012), and NDF determined with heat-stable alpha-amylase and inclusive of residual ash (**aNDF**; method 2002.04, AOAC International, 2012). Starch was analyzed at University of Florida according to the method of Hall (2015).

Mini-silos were thawed overnight in the refrigerator (approximately 4°C), and representative subsamples were collected from each silo to determine DM content, fermentation profile, and water-soluble carbohydrates (**WSC**). Samples were dried in duplicate for 48 h in a forced-air oven set at 60°C to determine DM content. Subsequently, samples were ground to pass a 1-mm screen in a Wiley mill (A. H. Thomas Scientific, Philadelphia, PA). Dried ground samples were analyzed for WSC concentration by the anthrone reaction assay (Ministry of Agriculture, Fisheries, and Food, 1986).

For fermentation profile, 20 g of wet samples of each mini-silo was diluted into 200 mL of distilled water and blended in a stomacher (Lab-Blender 400, Tekmar Company, Cincinnati, OH) set at high speed for 30 s, and the suspension was then filtered through 2 layers of cheesecloth. The extract was collected and used immediately for the determination of pH, ammonia-N, and organic acids. The pH was measured immediately in duplicate using a digital pH meter (Accumet XL25, Thermo Fisher Scientific Inc., Waltham, MA). Two 20-mL aliquots of extract were separated and treated with 0.2 mL of 50% sulfuric acid, centrifuged (7000 × *g*) for 15 min at 4°C, and the supernatant was frozen (−20°C) for subsequent analysis of organic acids and ammonia-N concentrations. Organic acids concentrations were determined as described by Muck and Dickerson (1988) using HPLC (Merck Hitachi Elite La-Chrome; Hitachi L2400, Tokyo, Japan). Briefly, a Bio-Rad Aminex HPX-87H ion exclusion column (300 × 7.8-mm i.d.; Bio-Rad Laboratories, Hercules, CA) was used in an isocratic elution system containing 0.015 *M* sulfuric acid in the mobile phase of HPLC with a UV detector (wavelength 210 nm; L-2400, Hitachi) and a flow rate