J. Dairy Sci. 98:1–11
http://dx.doi.org/10.3168/jds.2014-8768

Conservation, fiber digestibility, and nutritive value of corn harvested at 2 cutting heights and ensiled with fibrolytic enzymes, either alone or with a ferulic acid esterase-producing inoculant

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ABSTRACT

The aim of this study was to determine the effects of the use of a fibrolytic enzyme product, applied at ensiling either alone or in combination with a ferulic acid esterase-producing bacterial additive, on the chemical composition, conservation characteristics, and in vitro degradability of corn silage harvested at either conventional or high cutting height. Triplicate samples of corn were harvested to leave stubble of either a conventional (15 cm; NC) or high (45 cm; HC) height above ground. Sub-samples of chopped herbage were ensiled untreated or with a fibrolytic enzyme product containing xylanases and cellulases applied either alone (ENZ) or in combination with a ferulic acid esterase-producing silage inoculant (ENZ+FAEI). The fibrolytic enzyme treatment was applied at 2 mL of enzyme product/kg of herbage dry matter (DM), and the inoculant was applied at 1.3×10^5 cfu/g of fresh herbage. Samples were packed into laboratory-scale silos, stored for 7, 28, or 70 d, and analyzed for fermentation characteristics, and samples ensiled for 70 d were also analyzed for DM losses, chemical composition, and in vitro ruminal degradability. After 70 d of ensiling, the fermentation characteristics of corn silages were generally unaffected by cutting height, whereas the neutral detergent fiber, acid detergent fiber, and ash concentrations were lower and the starch concentration greater for silages made with crops harvested at HC compared with NC. After 70 d of ensiling, the acetic acid, ethanol concentrations, and the number of yeasts were greater, and the pH and neutral detergent fiber concentrations were lower, in silages produced using ENZ or ENZ+FAEI than the untreated silages, whereas ENZ+FAEI silages also incurred higher DM losses. No effect of additive treatment was observed on in vitro degradability indices after 48 h ruminal incubation. The use of a fibrolytic enzyme product, either alone or in combination with a ferulic acid esterase-producing inoculant, at ensiling did not improve corn silage fermentation or its nutritive value and resulted in some negative effects on these parameters. The effects of using a fibrolytic enzyme product at ensiling, either alone or in combination with a ferulic acid esterase-producing inoculant, did not differ between corn harvested at either NC or HC. Silage made from HC had a greater starch content and lower fiber content than NC silage, whereas cutting height did not affect the in vitro digestibility indices.

Key words: corn, fibrolytic enzyme, ferulic acid esterase, silage, additive

INTRODUCTION

Feed contributes a major input cost in animal production systems (Archer et al., 1999), and because grain prices are expected to remain high in coming years (Guyomard et al., 2013), the use of the forage components of ruminant diets needs to be maximized to improve the efficiency of livestock production systems. A primary limiting factor of forage utilization is fiber digestibility, with potentially under 600 g/kg of fiber available for digestion by the ruminant animal (Van Soest, 1994).

Previous studies have observed the potential benefits of the use of feed additives containing fibrolytic enzymes, primarily consisting of xylanases and cellulases, to improve the fiber digestibility of corn silage (Colombatto et al., 2004; Phakachoed et al., 2013) and other forages (Pinos-Rodríguez et al., 2002; Eun and Beauchemin, 2008; Elghandour et al., 2013) when applied to the feed just before feeding. However, the application of fibrolytic enzymes before the ensilage of corn may facilitate an increased duration of interaction between the forage and the applied enzymes, potentially allowing for a greater impact on the nutritive value of the subsequent silage. Furthermore, silage inoculants that contain ferulic acid esterase-producing bacteria have the potential to improve the nutritive value of corn silage and other preserved feeds through the degradation of the linkages between lignin and cell wall carbohydrates (Kang et al., 2009; Addah et al., 2012). Therefore, the application

Received August 21, 2014.
Accepted October 8, 2014.
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of a silage inoculant containing ferulic acid esterase-producing bacteria to corn silage in combination with exogenous fibrolytic enzymes may increase the opportunity for the hydrolysis of cell wall carbohydrates and enable a greater improvement in forage nutritive value than silages produced using fibrolytic enzyme products alone.

Previous studies indicate that the effects of fibrolytic enzymes on the nutritive value of forages can be highly variable, depending on a range of factors including plant variety, harvest maturity, and forage chemical composition (Sheperd and Kung, 1996; Pinos-Rodríguez et al., 2002; Elghandour et al., 2013). Corn silage consists of 2 contrasting components, the high-starch ear and the high-fiber stover. Harvesting the crop at a higher cutting height can improve the nutritive value, and alter the chemical composition, of the resultant silage through increasing the proportion of cob and decreasing the proportion of stover in the harvested herbage (Neylon and Kung, 2003; Caetano et al., 2011). Therefore, the magnitude of the effects of fibrolytic enzyme additives on the nutritive value of corn, and its subsequent preservation, harvested at contrasting cutting heights may differ, due to the contrasting chemical composition of the ensiled forage. Furthermore, the degree of potential enzyme additive effects on these herbages may be enhanced by the use of a ferulic acid esterase inoculant, as the degradation of linkages between lignin and cell wall carbohydrates can increase the potential substrate for fibrolytic enzyme hydrolysis.

The objective of this study was to determine the effect of the use of a fibrolytic enzyme product produced for ruminants, applied at ensiling either alone or in combination with a ferulic acid esterase-producing bacterial additive, on the chemical composition, conservation characteristics, and degradability of corn silage harvested at either a conventional or high cutting height.

MATERIALS AND METHODS

Triplicate samples of corn harvested at either a conventional or high cutting height were allocated to 1 of 3 additive treatments and ensiled in laboratory-scale silos for 1 of 3 durations of ensiling (n = 54 samples). The silage fermentation profile of samples was investigated after each ensiling duration, whereas the estimated nutritive value, in vitro digestibility, and aerobic stability were assessed after only 70 d of ensiling.

Forage Preparation

Forage corn (*Zea mays* L.; hybrid: 39T67; Pioneer Hi-Bred Ltd., Chatham, ON, Canada) was grown on a commercial farm in Iron Springs, Alberta, Canada (49°56′ N, 6°39′ W) in 2012. On September 27, for each of 2 plots (6 rows wide, 10 m long) allocated to either a normal cutting height (**NC**) or high cutting height (**HC**) in 3 replicate blocks, plots of corn were harvested at a target DM content of 300 g of fresh forage/kg using a CLAAS Jaguar 960 corn harvester (CLAAS of America, Omaha, NE) fitted with a corn processor and chopped to approximately 0.9 cm theoretical chop length. Plots allocated to NC were harvested to leave 15 cm of stubble above ground, whereas plots allocated to HC were harvested to leave 45 cm of stubble. For each plot, chopped forage was transported to Lethbridge Research Centre, Alberta, within 30 min of harvest, placed on a shaded polyethylene sheet, and mixed thoroughly. Subsequently, three 20-kg sub-samples were randomly taken, placed into pails, allocated to 1 of 3 additive treatments, and stored in a cool shaded area until ensiling.

Ensilage

Each 20-kg sub-sample was placed onto a polyethylene sheet, sprayed with half of the allocated treatment, mixed thoroughly, sprayed with the remaining treatment, and mixed a second time. Three treatments were used for this study consisting of either an untreated control of distilled water or a commercial enzyme product (**ENZ**; 75:25 mix of Cellulase PLUS and Xylanase PLUS, respectively; Dyadic International, Jupiter, FL), applied alone or in combination with a ferulic acid esterase-producing inoculant (**ENZ+FAEI**; Pioneer 11GFT, Pioneer Hi-Bred Ltd.). The xylanase activity of ENZ was 7,527 xylose equivalents·min^{-1}·mL^{-1} of enzyme, whereas the endoglucanase activity of ENZ was 420 μmol of glucose equivalents·min^{-1}·mL^{-1} of enzyme. The ENZ was applied at a rate of 2 mL/kg of forage DM, whereas the bacterial inoculant was applied at 1 g/1,000 kg of fresh forage to achieve 1.3×10^5 cfu/g of fresh forage for the ENZ+FAEI treatment. The inoculant contained a mixed bacterial culture of 1.0×10^{11} cfu/g of *Lactobacillus buchneri* LN4017 (ATCC no. PTA-6138) that produced ferulic acid esterase, 2.0×10^{10} cfu/g of *Lactobacillus plantarum* LP7109 (ATCC no. PTA-6139) and 1.0×10^{10} cfu/g of *Lactobacillus casei* LC3200 (ATCC no. PTA-6135). All treatments were diluted in distilled water and applied using a total volume of 3 mL/kg of fresh forage. Aseptic techniques were observed throughout ensiling to prevent contamination of samples. A 500-g sample of herbage was taken from each pile following treatment for microbial and chemical composition analyses.

Approximately 2.3 kg of herbage was packed into laboratory-scale polyvinyl chloride silos (10.4 cm di-