J. Dairy Sci. 100:1–9
https://doi.org/10.3168/jds.2016-11017

Exogenous β-mannanase improves feed conversion efficiency and reduces somatic cell count in dairy cattle

T. A. Tewoldebrhan,* J. A. D. R. N. Apphuamy,* J.-J. Lee,† M. Niu,* S. Seo,‡ S. Jeong,‡ and E. Kebreab*[1]
*Department of Animal Science, University of California, Davis 95616
†CTCBio Inc., Seoul, Republic of Korea 05842
‡Department of Animal Biosystem Sciences, Chungnam National University, Daejeon 305-764, Republic of Korea

ABSTRACT

Exogenous fibrolytic enzymes have been shown to be a promising way to improve feed conversion efficiency (FCE). β-Mannanase is an important enzyme digesting the polysaccharide β-mannan in hemicellulose. Supplementation of diets with β-mannanase to improve FCE has been more extensively studied in nonruminants than in ruminants. The objective of this study was to investigate the effects of β-mannanase supplementation on nutrient digestibility, FCE, and nitrogen utilization in lactating Holstein dairy cows. Twelve post-peak-lactation multiparous Holstein cows producing 45.5 ± 6.6 kg/d of milk at 116 ± 19.0 d in milk were randomly allotted to 1 of 3 treatments in a 3 × 3 Latin square design with 3 periods of 18 d (15 d for adaptation plus 3 d for sample collection). All cows were fed the same basal diet and the 3 treatments differed only by the β-mannanase dose: 0% dry matter (DM; control), 0.1% of DM (low supplement, LS), and 0.2% of DM (high supplement, HS) supplemented to the basal diet. Supplementation of β-mannanase enzyme at the LS dose reduced dry matter intake (DMI) but did not affect milk yield or milk composition. Cows receiving LS produced 90 g more milk per kg of DMI compared with control cows. Somatic cell count (SCC) in milk was lower for cows fed the LS diet compared with cows fed control diets. Cows fed LS diet had lower DM, organic matter and crude protein digestibility compared with cows fed control diets. Starch, neutral detergent fiber, and acid detergent fiber digestibility were not affected by LS. Milk yield, DMI, SCC, and nutrient digestibility did not change for HS. Despite the reduced crude protein digestibility, reduced N intake led to similar fecal N excretions in LS cows and control cows (234 vs. 235 g/cow per day). Urinary N excretions remained similar between enzyme-fed and control cows (~190 g/cow per day), although the percentage of N intake partitioned to urinary N tended to be greater in LS than in control cows (31 vs. 27%). Cows fed LS significantly improved the percentage of apparently absorbed N partitioned to milk protein N (42 vs. 38%). When supplemented at 0.1% of dietary DM, β-mannanase can improve FCE and lower the SCC of dairy cows without affecting milk yield, milk composition, or total manure N excretions of dairy cows.

Key words: β-mannanase, feed conversion efficiency, lactating cows, somatic cell count

INTRODUCTION

Improving feed conversion efficiency (**FCE**), which is the amount of product (e.g., milk yield) per unit of feed consumed, has a positive economic and environmental impact on a dairy enterprise. For example, within certain limits, greater inclusion of nonstructural carbohydrates in diets is often associated with greater milk yield per unit of DMI compared with diets with greater structural carbohydrates (Lascano et al., 2011). Increasing intake of available energy through improvement of fiber digestibility by exogenous fibrolytic enzymes can improve FCE. Although a considerable number of studies have shown increased milk production and ADG in ruminants, others did not observe improvement in FCE by using exogenous fibrolytic enzymes (Beauchemin et al., 2003). Exogenous xylanases and cellulases are the most commonly used fibrolytic enzymes for ruminants (Mendoza et al., 2014). Exogenous xylanase have been shown to increase total-tract digestibility of DM, NDF, and ADF in cattle (Yang et al., 2000), indicating that endogenous enzyme secretions in the rumen could be limiting, inefficient, or both, in attacking the substrate polysaccharides as target glycosidic bonds can be inaccessible to the active site of the enzymes (Boraston et al., 2004).

The polysaccharide β-mannan is an important component of the plant cell walls and can be classified into 4 groups: pure mannan, glucomannan, galactomannan, and galactoglucomannan (Moreira and Filho, 2008). Each of these plant cell wall polysaccharides present a

Received February 10, 2016.
Accepted September 10, 2016.
[1]Corresponding author: ekebreab@ucdavis.edu

backbone of β-1,4-linked mannose and glucose residues substituted with side chains of α-1,6-linked galactosyl side groups (Dea and Morrison, 1975). In contrast, a series of oligosaccharides containing α-1,2, α-1,3, and α-1,6 linkages have been isolated from yeast mannan. The mannosidic bonds in the β-mannans are hydrolyzed by β-mannanases found in glycoside hydrolase (**GH**) families 5 and 26 (Tailford et al., 2009), which also include cellulases and xylanases. Moreover, β-mannanases use mechanisms similar to those used by celluloses and xylanases in identifying and accessing the substrate (Sunna et al., 2001; Boraston et al., 2004). Hydrolysis of the β-mannans by β-mannanase releases mannan-oligosaccharides (**MOS**) of various lengths (Franco et al., 2004). Dietary supplementation of MOS has been shown to improve gastrointestinal health or overall health and performance of broilers (Yang et al., 2008), dogs (Swanson et al., 2002), and dairy calves (Heinrichs et al., 2003). Feeds containing high concentrations of β-mannan are palm kernel meal (30–35% of DM), palm kernel expeller (24% of DM), soybean hull (8% of DM), soybean meal (2% of DM) and sesame meal (3% of DM) (Dierick, 1989; Mok et al., 2013).

Saenphoom et al. (2013) reported the hemicellulose content of palm kernel expeller to decrease by 26% after treatment with β-mannanase. Lawal et al. (2010) reported that β-mannanase extracts from *Aspergillus niger* significantly increased hemicellulose digestibility in broilers fed palm kernel cake-based diets. Daskiran et al. (2004) reported that β-mannanase improved feed to gain ratio in broilers fed diets with soybean meal and guar gum. The effect of β-mannanase on FCE increased as guar gum content increased (Daskiran et al., 2004). Supplementation of β-mannanases has been shown to improve gain to feed ratios in pigs and broilers (Pettey et al., 2002; Kong et al., 2011; Cho and Kim, 2013; Lv et al., 2013) and feed digestibility in broilers, layers, and pigs (Wu et al., 2005; Kong et al., 2011; Mussini et al., 2011; Kim et al., 2013; Mok et al., 2013). However, greater FCE is not always related to digestibility improvements. Gharaei et al. (2012) and Zangiabadi and Torki (2010) demonstrated improvements in immune status parallel to increasing FCE in broilers for β-mannanase supplementations.

There is a paucity of information on β-mannanase produced by rumen bacteria. Nakai et al. (1994) examined degradation of β-mannan in the cultures of 26 strains of 9 species of rumen bacteria and found only 5 strains that degraded more than 20% of the β-mannan in culture media. About 80% of the strains were *Butyrivibrio fibrisolvens*. Fernando et al. (2010) showed that ruminal *Butyrivibrio fibrisolvens* populations declined by about 10-fold as the forage to concentrate ratio changed from 100:0 to 60:40 in cattle. Therefore, exogenous β-mannanase may enhance degradation of β-mannan in the rumen, when cows are fed total mixed rations containing high-mannan feeds such as palm kernel meal and soybean hulls. However, a recent study by Lee et al. (2014) showed no changes in total-tract CP or NDF digestibility in 6-mo-old goats for β-mannanase supplementation, even though it improved ADG, FCE, and N retention. Arndt et al. (2015) demonstrated that dairy cows with greater FCE were associated with lower SCC and greater N partitioning to milk protein compared with cows with lower FCE. The objective of this study was to investigate the effects of exogenous β-mannanase supplementation on nutrient digestibility, FCE, SCC, and N partitioning in lactating dairy cows.

MATERIALS AND METHODS

Animals and Treatments

All animal procedures were approved by Institutional Animal Care and Use Committee at the University of California-Davis. The experiment was conducted at the Teaching and Research Facilities of the Department of Animal Science at the University of California-Davis. Twelve post-peak-lactation multiparous Holstein cows with an average of 696 ± 47 kg of BW, 45.5 ± 6.6 kg/d of milk yield, and 116 ± 19.0 DIM at the beginning of the experiment were housed in a freestall barn equipped with Calan gates (American Calan, Northwood, NH). Cows were assigned to 3 treatments in a 3-period crossover design, where treatment sequences were balanced using 3 × 3 Latin squares to mitigate possible carryover effects. The treatments were a basal TMR diet only or supplemented with 2 doses of a commercially available β-mannanase enzyme (CTCZYME, patent 100477456–0000; CTC Bio Inc., Seoul, South Korea). The CTCZYME product contains pure β-mannanase, which is produced using a gene encoding mannanase of *Bacillus subtilis* WL-7 cloned into *Escherichia coli*. The mannanase gene encodes a polypeptide of 362 amino acids, the sequence of which is highly homologous to those of mannanases belonging to GH family 26. Kweun et al. (2004) reported that the enzyme had a pH optimum at 6.0 and a temperature optimum at 55°C. The activity of the enzyme was estimated to be 800,000 U/kg at pH 4.0 and 30°C (Kim et al., 2013). The enzyme was active on mannan sources such as locust bean gum, konjak, and guar gum, and it did not exhibit activity toward yeast mannan, carboxymethylcellulose, β-glucan, or xylan. The CTCZYME β-mannanase was previously tested in broilers (Kong et al., 2011; Mussini et al., 2011; Ferreira et al., 2016), pigs (Yoon et al., 2010; Kim et al., 2013), goats (Lee et al., 2014), and growing heifers (Seo et al., 2016). The enzyme product is available in