J. Dairy Sci. 101:1–12
https://doi.org/10.3168/jds.2017-12776

Effects of rumen-degradable protein:rumen-undegradable protein ratio and corn processing on production performance, nitrogen efficiency, and feeding behavior of Holstein dairy cows

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ABSTRACT

This study was conducted to investigate the effects of the ratio of rumen-degradable protein (RDP) to rumen-undegradable protein (RUP) and corn processing method on production performance, nitrogen (N) efficiency, and feeding behavior of high-producing Holstein dairy cows. Twelve multiparous Holstein cows (second parity; milk yield = 48 ± 3 kg/d) were assigned to a replicated 4 × 4 Latin square design with a 2 × 2 factorial arrangement of treatments. Factor 1 was corn processing method [ground corn (GC) or steam flaked corn (SFC) with a flake density of about 390 g/L], and factor 2 was RDP:RUP ratio [low ratio (LR) = 60:40; high ratio (HR) = 65:35] based on crude protein (%). The crude protein concentrations were kept constant across the treatments (16.7% of DM). No significant interactions of main treatment effects occurred for lactation performance data. Cows fed 2 different RDP:RUP ratios exhibited similar dry matter intake (DMI), but those fed SFC showed decreased feed intake compared with those receiving GC (25.1 ± 0.48 vs. 26.2 ± 0.47 kg/d, respectively). Cows fed HR diets produced more milk than did those fed LR diets (44.4 ± 1.05 vs. 43.2 ± 1.05 kg/d, respectively). Milk fat content decreased but milk protein content increased in cows fed SFC compared with those fed GC. Feed efficiency (i.e., milk yield/DMI) was enhanced with increasing ratio of RDP:RUP (1.68 ± 0.04 vs. 1.74 ± 0.04 for LR and HR, respectively). Apparent N efficiency was higher in cows fed HR than in those fed LR (30.4 ± 0.61 vs. 29.2 ± 0.62, respectively). Compared with cows fed the GC-based diet, those receiving SFC exhibited lower values of N intake, N-NH_3 concentration, and fecal N excretion. Cows receiving SFC-based diets spent more time ruminating (min/kg of DMI) than did those fed GC. Although these results showed no interaction effects of RDP:RUP ratio and corn processing method on performance, higher RDP:RUP ratios and ground corn can be effective feeding strategies for feed to lactating cows receiving high-concentrate diets.

Key words: rumen-undegradable protein, rumen-degradable protein, corn processing, nitrogen efficiency, dairy cow

INTRODUCTION

The efficiency of dietary CP [nitrogen (N) × 6.25] consumption is higher in dairy cows than in any other ruminants. However, they excrete about 2 to 3 times more N in their manure than in their milk (Broderick, 2003; Bahrami-Yekdangi et al., 2014), which results in increased milk production costs and environmental concerns related to N pollution. It is well established that the amount of protein degraded in the rumen increases with increasing CP content of the diet. If RDP exceeds the microbial requirements, then large amounts of NH_3 are produced, absorbed into the blood, converted into urea in the liver, and excreted in the urine. In the manure, urinary urea can be rapidly hydrolyzed to NH_3 and released by volatilization into the environment (Muck, 1982). The goal in protein nutrition should be optimizing N efficiency, which means minimizing total N intake while at the same time adequately meeting the requirements for milk protein synthesis and, thereby, reducing feeding costs and N excretion into the environment.

Ruminally synthesized microbial CP (**MCP**), RUP, and, to a much lesser extent, endogenous CP contribute to the passage of MP into the small intestine (NRC, 2001). The MP is defined as the true protein that is digested postruminally and available for absorption by the small intestine. In high-producing cows, MCP supplies a lower portion of the protein requirement; therefore, significant amounts of the dietary protein must escape ruminal degradation to meet the animal's protein requirements (Broderick, 2006b; Bahrami-Yekdangi et al., 2014). However, it has been demonstrated

Received February 21, 2017.
Accepted October 14, 2017.
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that RUP overfeeding due to an imbalanced AA profile reduces the efficiency of MP utilization for milk protein synthesis; therefore, the nutritive value of MP is determined by its profile of essential AA (Broderick, 2006a; Schwab et al., 2007). To meet the requirements for MP without excessive N, rations must also be balanced for RUP and RDP.

Protein and carbohydrates are the 2 major nutrients included in the diets of dairy cows (Santos et al., 1998a, 1999). The balanced supply of carbohydrates and protein contributes to increased animal performance, enhanced feed efficiency, and reduced environmental pollution. One way to improve the efficiency of N consumption is to use dietary carbohydrates as a source of fermentable energy so that ruminal fermentation of carbohydrates is adapted to ruminal protein degradation (Broderick, 2006a). Corn grain is the most common feed used as an energy source in ruminant rations. As the whole grain is almost completely resistant to microbial digestion in the rumen, different methods of grinding or steam flaking have been used to enhance ruminal carbohydrate availability for improved performance and feed efficiency in dairy cattle (Dhiman et al., 2002; Ferraretto et al., 2013; Shen et al., 2015). Chemical and structural changes in starch granules may be induced by the simultaneous manipulation of factors such as moisture, temperature, and pressure in steam flaking to increase the proportion of starch digested in the rumen and its total digestibility (Theurer et al., 1999; Nikkhah et al., 2004; Zhong et al., 2008).

Several studies have reported no improvements in milk or protein production by increasing dietary CP from 16.5 to 18.5% (Broderick, 2003; Leonardi et al., 2003; Bahrami-Yekdangi et al., 2014). However, the supply of AA for dairy cows can be enhanced by 2 sources: by increasing the level of RUP and by increasing the production of MCP in the rumen. We hypothesized that steam flaking corn will reduce RUP concentration in dairy cow diets by increasing MCP synthesis. We are aware of no studies considering the effects of RDP:RUP ratio (in a constant CP content) and corn processing on the performance of early-lactation cows. Thus, the objective of this study was to investigate the effects of 2 corn processing methods, 2 RDP:RUP ratios, and their interactions on the performance, feed intake, and feeding behavior of high-producing dairy cows.

MATERIALS AND METHODS

Location and Treatments

This experiment was conducted at the Dairy Facilities of the Lavark Research and Teaching Farm (Isfahan University of Technology, Isfahan, Iran). Animals were cared for according to the guidelines of the Iranian Council of Animal Care (1995).

This study was conducted using 12 high-producing multiparous Holstein cows (second parity; 72 ± 12 DIM; milk yield = 48 ± 3 kg/d) in a replicated 4 × 4 Latin square design with 4 treatments and 3 replicates (cows) during 4 periods of 21 d (16 d for diet adaptation and 5 d for data collection). To minimize carryover effects, the animals within the squares were randomly assigned to 1 of 4 experimental diet sequences in a 2 × 2 factorial arrangement. Two corn processing methods and 2 RDP:RUP ratios were combined to yield 4 dietary treatments: (1) finely ground corn (**GC**) with a low RDP:RUP ratio (**LR**; RDP = 60% of CP), (2) finely GC with a high RDP:RUP ratio (**HR**; RDP = 65% of CP), (3), steam flaked corn (**SFC**) corn with a low RDP:RUP ratio, and (4) SFC with a high RDP:RUP ratio. Changes in RDP:RUP ratios of dietary treatments were accomplished by replacing xylose-treated soybean meal (**SBM**; a source of RUP; Yasna-Mehr Co., Tehran, Iran) with SBM (a source of RDP).

Protein degradability (% CP) of all feed ingredients was determined by the Cornell net carbohydrate and protein system method (Sniffen et al., 1992; Licitra et al., 1996). Because of the importance of the difference in RUP concentration of SBM and xylose-treated SBM in this study, the feed protein fractions (A, B, and C; % of CP) and rate of degradation for these protein sources were determined by the in situ method (Ørskov and McDonald, 1979). To determine the RDP and RUP content of SBM and xylose-treated SBM, bags (polyester, 10 cm × 20 cm, with a 50-μm pore size) containing 5 g of each protein source were placed in duplicate in the rumen for 0, 1, 2, 4, 8, 16, 24, 36, and 48 h. Bags were then rinsed under running tap water until all feed residues were rinsed to the bottom of the bag. The bags then were allowed to drain for 3 to 5 h and were dried in a forced-air oven (55°C, 48 h) and weighed. Two blank bags for each time exposure were incubated with the samples, and N of the blank samples was subtracted from the residual. Kjeldahl analysis was performed on the remaining sample to determine N content.

The exponential equation of Ørskov and McDonald (1979) was fitted to values for ruminal degradation of N versus time. Curves were fitted to estimate the soluble (A) and insoluble potentially degradable (B) fractions and rate of degradation (k_d). Fraction C was calculated as 1 − (A + B). The RDP and RUP values (% CP) were calculated (NRC, 2001) using the following equations:

$$RDP = A + B \times [k_d/(k_d + k_p)]$$