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Precision-feeding dairy heifers a high rumen-degradable protein diet with different proportions of dietary fiber and forage-to-concentrate ratios

G. J. Lascano,*[1] L. E. Koch,* and A. J. Heinrichs†
*Department of Animal and Veterinary Sciences, Clemson University, SC 29634
†Department of Animal Sciences, The Pennsylvania State University, University Park 16802

ABSTRACT

The objective of this experiment was to determine the effects of feeding a high-rumen-degradable protein (RDP) diet when dietary fiber content is manipulated within differing forage-to-concentrate ratio (F:C) on nutrient utilization of precision-fed dairy heifers. Six cannulated Holstein heifers (486.98 ± 15.07 kg of body weight) were randomly assigned to 2 F:C, low- (45% forage; LF) and high-forage (90% forage; HF) diets and to a fiber proportion sequence [33% grass hay and wheat straw (HS), 67% corn silage (CS; low fiber); 50% HS, 50% CS (medium fiber); and 67% HS, 33% CS (high fiber)] within forage proportion administered according to a split-plot, 3 × 3 Latin square design (16-d periods). Heifers fed LF had greater apparent total-tract organic matter digestibility coefficients (dC), neutral detergent fiber, and cellulose than those fed LC diets. Substituting CS with HS resulted in a linear reduction in dry matter, organic matter, and cellulose dC. Nitrogen dC was not different between F:C or with increasing proportions of HS in diets, but N retention tended to decrease linearly as HS was increased in the diets. Predicted microbial protein flow to the duodenum decreased linearly with HS addition and protozoa numbers HS interacted linearly, exhibiting a decrease as HS increased for LF, whereas no effects were observed for HF. Blood urea N increased linearly as HS was incorporated. The LF-fed heifers had a greater ruminal volatile fatty acids concentration. We noted a tendency for a greater dry matter, and a significantly higher liquid fraction turnover rate for HF diets. There was a linear numerical increase in the liquid and solid fraction turnover rate as fiber was added to the diets. Rumen fermentation parameters and fractional passages (solid and liquid) rates support the reduction in dC, N retention, and microbial protein synthesis observed as more dietary fiber is added to the rations of dairy heifers precision-fed a constant proportion of rumen-degradable protein.

Key words: heifer, dietary fiber, rumen-degradable protein, precision feeding

INTRODUCTION

The ruminant animal is unique in its ability to survive on a diet consisting entirely of NPN (Van Soest, 1994), but its growth cannot be sustained solely by rumen microbial protein synthesis (Merchen and Titgemeyer, 1992). Microbial protein contribution from RDP can represent from 50 to 80% of the AA absorbed (Storm and Orskov, 1983; Clark et al., 1992); hence, RUP is also needed to supply the required AA to the rapidly growing heifer. But, even when supplemental protein is provided, microbial protein synthesis must be maximized to take advantage of this unique characteristic (Johnson et al., 1998; Bach et al., 2005). Research on the effect of protein degradability in dairy heifer diets is scarce. Zanton and Heinrichs (2009) suggested an optimal N intake for heifers limit-fed either a high- or low-forage diet of 1.67 g of N/kg of $BW^{0.75}$, but protein rumen degradability was not assessed. Gabler and Heinrichs (2003) and Zanton et al. (2007) studied the effect of manipulating RDP in dairy heifers fed only high-forage diets (**HF**), and observed no difference in N utilization even when some fermentation parameters were affected. Both studies agreed that the effects observed were dependent on forage-to-concentrate ratios (**F:C**) and nutrient concentrations.

Precision feeding dairy heifers can be accomplished by modifying F:C in numerous ways and can result in different dietary fiber proportions, thus changing the dynamics of how nutrients interact. Passage rates (**kp**) are typically higher in the growing heifer due to a smaller rumen capacity (Van Soest, 1994), affecting the synchrony at which nutrients are used at the rumen level. Additionally, kp can be slower when intake is limited, especially in low-forage diets (**LF**; Eng et al., 1964; Owens and Isaacson, 1977; Colucci et al., 1990), resulting in reduced rumen bacterial and feed N flow to the small intestine (Murphy et al. 1994). However,

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[1]Corresponding author: glascan@clemson.edu

when optimal ruminal interaction between protein and carbohydrate has been achieved, results suggest improved nutrient utilization (Nocek and Russell, 1988). Hoover and Stokes (1991) reported increased ADG with an NSC-to-RDP ratio of 3.30 and hypothesized that synchronizing NSC-to-RDP ratios may increase AA flow to the small intestine and maximize the efficiency of protein used for growth. Similarly, CP-to-ME ratios of around 55 g/Mcal per day have enhanced ADG and nutrient utilization (Lammers and Heinrichs, 2000; Gabler and Heinrichs, 2003).

In a recent study in which dairy heifers were precision-fed different dietary fiber proportions within 2 different F:C treatments, N retention was increased quadratically in the LF diet whereas the opposite effect was observed for HF diets (Lascano and Heinrichs, 2011). Similar patterns in microbial protein flow to the duodenum and N retention suggest that, in a limited intake scenario, synchrony between fiber, kp, F:C, and protein degradability can be manipulated to increase N utilization in dairy heifers. Therefore, the hypothesis of the current experiment was that high RDP would differentially improve N utilization depending on the fiber content HF and LF diets precision-fed to dairy heifers. The objective was to determine the effects of feeding a high-RDP diet when dietary fiber content is manipulated within differing F:C on nutrient digestibility, nitrogen utilization, and rumen fermentation of precision-fed dairy heifers. An additional objective was to determine if fractional kp were affected by F:C and incremental dietary fiber proportions under precision feeding conditions.

MATERIALS AND METHODS

Animals and Experimental Design

All procedures involving animals were approved by the Pennsylvania State University Institutional Animal Care and Use Committee. Six Holstein rumen-cannulated heifers, 15.56 ± 0.45 mo of age and 486.98 ± 15.07 kg of BW, were randomly assigned to 2 F:C, LF (45% forage) and HF (90% forage), and to a forage combination sequence to modify dietary fiber content [33% of forage in proportionally equal combination of grass hay and wheat straw (**HS**), 67% corn silage (**CS**; low-fiber treatment); 50% HS, 50% CS (medium-fiber treatment); and 67% HS, 33% CS (high-fiber treatment)] within F:C. Heifers were assigned to a split-plot, 3 × 3 Latin square design with 16-d periods. The whole-plot factor was the diet F:C, and the subplot was fiber proportion within the forage fraction of the diet. Specifically, heifers were offered a basal HF or LF diet containing a low-, medium-, or high-fiber forage combination. Similar N intake and RDP were provided (1.20 g of N/kg of $BW^{0.75}$), and casein was added to supply additional N to provide 1.80 g of N/kg of $BW^{0.75}$, which has been observed to maximize N utilization in dairy heifers (Zanton and Heinrichs, 2009). Diets were provided as a TMR and calculated to provide equal intakes of ME and to allow for 800 g/d of ADG. Adaptation to treatment rations (dietary fiber) were made over the first 11 d of each period; on d 12, sample collection began. Basal diets are presented in Table 1. Heifer BW were measured daily 2 h before and weighted averages used to determine amount of feed offered for the following 8-d interval. Rations were mixed daily at 1200 h by preparing the LF and HF diets with the different fiber combinations individually. Heifers were fed daily at 1000, 1600, and 2400 h with sodium caseinate (American Casein Company, Burlington, NJ) added to the basal diet to obtain the RDP content proposed. Heifers were housed in individual stalls (117 × 302 cm) in a mechanically ventilated tiestall barn with rubber mattress bedding and were allowed access to an exercise lot for 2 h before the 1000 h feeding on nonsampling days. Time (min) required to finish a meal was recorded, and water was available ad libitum with daily individual consumption monitored via unidirectional flow meters (Sensus Metering Systems, Uniontown, PA).

Fecal, Urine, and Feed Sample Collection and Analysis

Feces and urine were collected from d 12 to 14 (2 d of total collection). Urine was collected via modified urine device (Lascano et al., 2010), weighed, and subsampled daily after feeding. A 250-mL subsample was frozen at −20°C for further analysis. Urine pH was monitored and acidified to pH <2 by the addition of 12 *N* HCl as required to minimize NH_3 volatilization (Zanton and Heinrichs, 2009). Feces were collected hourly and stored in airtight containers; every 24 h the total collection of feces was mixed, weighed, recorded, and subsampled. Feedstuffs, TMR, feces (dry basis), and urine (wet basis) were composited by period. Samples were dried in a 55°C forced-air oven for 4 d, ground through a 1-mm screen using a Wiley Mill (Arthur H. Thomas, Philadelphia, PA), and analyzed for DM, OM, ash (AOAC, 2000), ADF, ADL, and NDF (Van Soest et al., 1991) using an Ankom^{200} Fiber Analyzer (Ankom Technology Corporation, Fairport, NY), with heat-resistant α-amylase and sodium sulfite used in the NDF procedure. Starch was analyzed on reground samples (<0.5-mm screen) using a modified procedure reported by Zanton and Heinrichs (2009). Freeze-dried feed and fecal samples were pulverized using Mixer Mill MM 200 (Retsch GmbH, Haan, Germany) and