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Efficiency and rumen responses in younger and older Holstein heifers limit-fed diets of differing energy density[1]

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ABSTRACT

The objective of this study was to evaluate the effects of limit feeding diets of different predicted energy density on the efficiency of utilization of feed and nitrogen and rumen responses in younger and older Holstein heifers. Eight rumen-cannulated Holstein heifers (4 heifers beginning at 257 ± 7 d, hereafter "young," and 4 heifers beginning at 610 ± 16 d, hereafter "old") were limit-fed high [HED; 2.64 Mcal/kg of dry matter (DM), 15.31% crude protein (CP)] or low (LED; 2.42 Mcal/kg of DM, 14.15% CP) energy density diets according to a 4-period, split-plot Latin square design with 28-d periods. Diets were limit-fed to provide isonitrogenous and isoenergetic intake on a rumen empty body weight (BW) basis at a level predicted to support approximately 800 g/d of average daily gain. During the last 7 d of each period, rumen contents were subsampled over a 24-h period, rumen contents were completely evacuated, and total collection of feces and urine was made over 4 d. Intakes of DM and water were greater for heifers fed LED, although, by design, calculated intake of metabolizable energy did not differ between age groups or diets when expressed relative to rumen empty BW. Rumen pH was lower, ammonia (NH_3-N) concentration tended to be higher, and volatile fatty acids (VFA) concentration was not different for HED compared with LED and was unaffected by age group. Rumen content mass was greater for heifers fed LED and for old heifers, so when expressing rumen fermentation responses corrected for this difference in pool size, NH_3-N pool size was not different between diets and total moles of VFA in the rumen were greater for heifers fed LED, whereas these pool sizes were greater for old heifers. Total-tract digestibility of potentially digestible neutral detergent fiber (NDF) was greater in heifers fed LED and for young heifers, whereas the fractional rate of ruminal passage and digestion of NDF were both greater in heifers fed LED. Digestibility of N was greater for heifers fed HED, but was unaffected by age group, whereas the efficiency of N retention was greater for heifers fed HED and for young heifers. Manure output was reduced in heifers fed HED, but the effect was largest in old heifers. Results confirm previous studies in which young heifers utilize N more efficiently than old heifers, primarily through greater efficiency of postabsorptive metabolism. Results also support the concept of limit feeding HED diets as a potential means to reduce manure excretion and increase nitrogen efficiency.
Key words: dairy heifer, limit feeding, efficiency

INTRODUCTION

Dairy cattle production efficiency depends on multiple factors associated with the nutrition, reproduction, management, and genetics of the lactating cows. Additionally, the heifer-rearing program has a significant effect on whole-farm production efficiency (Tozer and Heinrichs, 2001). For instance, lifetime feed efficiency (cumulative milk production/cumulative DMI) does not exceed 1 until toward the end of the first lactation using realistic assumptions (i.e., from the NRC, 2001) on heifer DMI, ADG, lactation DMI, and milk production. Opportunities exist to increase the nutritional efficiency of raising heifers from birth to calving using limit feeding of higher energy density diets to meet but not exceed energy requirements for an optimal level of ADG. Managing dairy heifer nutrition over a range of diets and with a range of heifer ages with limit feeding has shown that heifers can maintain a similar level of structural growth (Zanton et al., 2007; Lascano et al., 2008), have increased feed efficiency (ADG:DMI; Zanton and Heinrichs, 2007; Hoffman et al., 2007), reduced excreta output (Moody et al., 2007; Lascano et al., 2008), and similar levels of milk production in the first lactation (Zanton and Heinrichs, 2010). To apply limit feeding on-farm requires more intensive management of the dairy heifer housing and nutrition than is typi-

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cally practiced using conventional heifer management and feeding practices. Additionally, negative changes in rumen fermentation could be anticipated depending on the energy density of the diet and feeding management.

Application of limit feeding has been studied in pre- and postpubertal dairy heifers in different studies; however, little data exist that would guide recommendations across these groups where a common diet was fed. Moody et al. (2007) found that when corn silage was the sole forage, low corn silage diets that were limit-fed to 6- or 12-mo-old Holstein heifers were utilized more efficiently than the high corn silage diets. Dry matter digestibility tended to be improved for the older heifers, although the efficiency of N retention tended to be improved for younger heifers. Zanton and Heinrichs (2008) determined that nitrogen retention was affected by an interaction between BW, ME intake, and N intake, wherein a decline in N retention [g of N/kg of metabolic BW ($BW^{0.75}$)] occurred with increasing animal BW and this decline was greater for animals with a higher energy intake. This confirmed previous work by Blaxter et al. (1966), in which it was determined that the efficiency of N retention declined with age in 3 growing Ayrshire steers fed a common diet at 3 different levels of intake.

Limiting intake and reducing the level of forage in the diet would be predicted to decrease rate of passage of feed from the rumen, potentially increasing diet digestibility in the rumen (Colucci et al., 1990; NRC, 2001). These dietary changes would also be predicted to increase rumen digestibility because of the higher proportion of more fermentable feedstuffs. Possibly counterbalancing these effects would be an expected decrease in rumen pH due to the greater energy density of the diet, thus resulting in a decrease in the rate of digestion (Mould et al., 1983; Grant and Mertens, 1992). Given the possible interactions among these different factors, the effects of limit feeding higher or lower digestibility diets to younger and older dairy heifers is unknown. Therefore, the objective of this study was to evaluate the effects of limit feeding diets of different predicted energy density on the efficiency of utilization of feed and nitrogen and the rumen responses in younger and older Holstein heifers. Our hypothesis was that limit feeding diets of different energy densities to dairy heifers would change nutritional efficiency and affect rumen fermentation.

MATERIALS AND METHODS

Animals and Treatments

To accomplish the objective of this experiment, 8 nonpregnant Holstein heifers were selected from the Penn State dairy herd based on selection criteria for age and BW. The use of animals and all procedures involving the use of animals were approved by the Pennsylvania State University Institutional Animal Care and Use Committee. Heifers selected were classified as younger (hereafter "young" heifers; 257 ± 7 d old and 221 ± 9 kg of BW at the initiation of the experiment; mean ± SD) or older (hereafter "old" heifers; 610 ± 16 d old and 537 ± 16 kg of BW at the initiation of the experiment; mean ± SD). Heifers were surgically prepared with a rumen cannula under local anesthesia at least 2 mo before the initiation of sample collection (rumen cannulas were either 10.16 or 7.62 cm i.d. for old and young heifers, respectively). Heifers were housed in individual tiestalls in a mechanically ventilated barn for the duration of the experiment except on days on which sampling was not conducted, when heifers were allowed access to a paved exercise lot for approximately 2 h before the morning feeding.

Feed was mixed once daily (Super Data Ranger, American Calan, Northwood, NH) at approximately 1500 h; 50% of the daily allotment was delivered fresh at 2000 h and 50% was stored in refrigeration overnight for feeding at 0800 h the next morning. Treatment diets were formulated to be lower or higher in predicted energy density (**LED** or **HED**, respectively; Table 1). Corn silage DM was determined thrice weekly to adjust the as-fed diet mixture; additionally, water was added to HED as needed to lower the formulated ration DM to 65% to reduce dustiness. Treatment diets were formulated to provide an equal amount of predicted ME and CP per rumen empty metabolic BW (**$REBW^{0.75}$**), where REBW was calculated from measured full BW and measured rumen content weight (ME and CP prediction based on NRC, 2001 at a level to support ~800 g/d of ADG). On the day before initiation of the experiment and every 14 d thereafter, heifers were weighed before the morning and evening feeding and had rumen contents evacuated, weighed, and subsampled at the midpoint between feedings (1400 h); these data were used to allocate the feed DM offered for the subsequent 14 d.

Experimental Design and Sample Collection

Experiment was designed as a split-plot, 4-sequence, 4-period changeover design to account for the potential for carryover effects of previous treatment (design 4.4.13 from Jones and Kenward, 2003). In this design, heifer age category was the whole plot and nutritional treatments applied according to a crossover design were the subplots. Periods were 28 d in length, with the first 21 d for adaptation and the last 7 d for sampling. Feed and refusal (if any) samples were collected daily and