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Manipulation of Soluble and Rumen-Undegradable Protein in Diets Fed to Postpubertal Dairy Heifers[1]

G. I. Zanton, M. T. Gabler,[2] and A. J. Heinrichs[3]
Department of Dairy and Animal Science, The Pennsylvania State University, University Park 16802

ABSTRACT

Eight postpubertal Holstein heifers (455 ± 4.0), fit with rumen cannulas, were used in 2 experiments to investigate the effects of altering dietary protein type on nutrient digestibility, rumen fermentation, and nitrogen utilization. Heifers were fed diets containing low or high levels of soluble (SP) and low or high levels of rumen-undegradable protein (RUP) in a 4 × 4 Latin square design with a 2 × 2 factorial arrangement of treatments. The treatment rations in experiment 1 were formulated with corn silage composing the majority of the forage fraction, whereas in experiment 2, grass hay composed the highest proportion of ration DM. Blood and rumen samples were collected over 2 d and total fecal and urine collections were conducted for 4 d. Dry matter, organic matter, and neutral detergent fiber digestibility were not different in either experiment 1 or 2. Increasing the proportion of dietary crude protein that was SP increased mean daily rumen ammonia concentrations in each experiment, although no other rumen parameter differed. Excretion of urinary nitrogen in experiment 1 was highest for diets with low SP and low RUP and with high SP and high RUP, which resulted in these rations being the least efficient in retention of apparently digested nitrogen. The proportion of consumed or absorbed nitrogen retained in experiment 2 was not significantly different between treatments. Responses to alterations in crude protein degradability are observable in postpubertal heifers; however, the level of response may depend on the diet in which protein degradability is altered.

Key words: heifer, rumen fermentation, nitrogen utilization, forage

INTRODUCTION

Growing heifers require AA to support maintenance, growth, and pregnancy. Providing these nutrients as efficiently as possible requires a coordinated effort between dietary provision, availability, and preabsorptive and postabsorptive processes. Ruminants have the capacity to utilize NPN sources alone or in combination with protein N to meet their AA needs (Loosli et al., 1949; Virtanen, 1966; Satter and Roffler, 1975). However, the efficiency with which dietary protein can be utilized for tissue growth is relatively low (Lobley, 1992). Ammonia is the preferred source of N for cellulolytic bacteria (Bryant and Robinson, 1961). Furthermore, fermentation has been shown to be most efficient if NH_3 is present at a concentration of at least 5 mg/dL in continuous culture (Satter and Slyter, 1974), although AA and peptides are also important (Argyle and Baldwin, 1989). Dairy heifers are typically fed rations with a high quantity of forage and a high concentration of NDF. Therefore, feeding growing heifers a protein source with higher levels of solubility may improve nutrient efficiency. However, the suggestion has been made that greater proportions of slowly degraded CP also may improve fiber digestion by enabling a more consistent supply of nitrogenous compounds to the rumen microbial population (Veen, 1986).

Although much of the AA requirement for the ruminant is met by microbial sources (Allison, 1969; Merchen and Titgemeyer, 1992), there has been considerable interest in supplying a significant portion of dietary CP to dairy heifers in the form of RUP (Casper et al., 1994; Bethard et al., 1997; Tomlinson et al., 1997). Amos (1986) and Tomlinson et al. (1997) found that increasing the proportion of RUP led to greater gains and gain efficiencies. Moallem et al. (2004) found few statistical differences in slaughtered heifers fed diets varying in RUP concentration. Gabler and Heinrichs (2003a) indicated in a digestibility experiment that, although some rumen parameters were altered by changing the protein fractions, digestibility and N utilization were not affected. Each of the preceding experiments used heifers between 3 and 10 mo of age, whereas the majority of time, growth, and feed consumed throughout the life of a heifer occurs after this time

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[2]Current address: ADM Alliance Nutrition, Box 44037, Madison WI 53744.
[3]Corresponding author: ajh@psu.edu

frame. Because nutrient requirements and DMI differ with increasing BW of older heifers, it may not be possible to extrapolate results from experiments with younger animals.

Because of the effects that soluble protein (**SP**) and RUP may have on N efficiency and nutrient utilization, 2 experiments were conducted to examine the effects of altering dietary protein fractions fed to postpubertal dairy heifers. The experimental objectives were to evaluate nutrient digestibility, rumen fermentation, and N utilization in postpubertal dairy heifers given diets containing 2 levels of forage differing in the proportions of SP and RUP.

MATERIALS AND METHODS

Animals, Treatments, and Experimental Design

All procedures involving the use of animals in these experiments were approved by the Pennsylvania State University Institutional Animal Care and Use Committee. These experiments were conducted over the course of 2 yr, using 8 cannulated heifers in 2 separate 4 × 4 Latin squares. The 4 experimental periods consisted of 20 or 21 d for experiments 1 and 2, respectively: The first 10 d were used for adaptation to the treatment rations, and samples were collected over the remaining days.

Within each experiment, heifers were fed a diet with the forage component based on grass hay and corn silage, with corn silage composing a greater proportion of DM in experiment 1 and grass hay composing a greater proportion of DM in experiment 2. Experimental diets and their composition are shown in Tables 1 and 2 for experiments 1 and 2, respectively. Treatments were in a 2 × 2 factorial arrangement with the main effects being level of SP, level of RUP, and their interaction. Every 10 d, BW was recorded for 2 consecutive days; measurements were conducted 3 h after feeding and DMI was adjusted for the following 10 d. Treatment rations were provided to each heifer at 2% of BW per day once daily at 0930 h (experiment 1) and at 0900 h (experiment 2), and any refusals were collected immediately prior to feeding. Samples of forages and rations were collected 3 times weekly and concentrate samples were collected once per week and composited by period for chemical analysis.

Each of the 8 heifers that was used in these experiments was surgically modified for a previous experiment with a rumen cannula (3.81 cm i.d.; Bar Diamond, Parma, ID) under local anesthesia. Heifers were housed in individual tie stalls in a mechanically ventilated barn for the duration of the experiment, except on days during which samples were not collected. For approximately 2 h on these days, heifers were allowed access to an exercise lot.

Table 1. Ingredient and nutrient composition of treatment rations containing low and high levels of soluble protein (SP) and low and high levels of RUP in experiment 1

	Low SP		High SP		
	Low RUP	High RUP	Low RUP	High RUP	SEM
Ingredient, % of DM					
Grass hay	22.58	22.50	22.59	22.44	—
Corn silage	49.88	49.71	49.90	49.58	—
Wheat middlings	2.46	1.23	1.97	0	—
Cottonseed hulls	6.79	7.35	7.38	12.22	—
HM shelled corn	6.64	6.62	8.61	4.89	—
Urea 45% N	0	0	0.59	0.49	—
48% SBM[1]	7.38	3.68	0.98	0	—
SBM–expeller	2.46	5.88	6.15	7.33	—
Fish meal	0	1.23	0	1.22	—
Ca sulfate	0.20	0.20	0.05	0.05	—
Aragonite	0.84	0.83	0.05	0.05	—
Magox 54% Mg	0.30	0.29	0.05	0.05	—
Salt	0.34	0.34	0.34	0.34	—
Selenium 0.06%	0.05	0.05	0.30	0.29	—
Vitamins A, D, and E[2]	0.05	0.05	0.84	0.83	—
Dairy TM II[3]	0.05	0.05	0.20	0.20	—
Composition					
DM, % as fed	61.23	61.65	59.78	59.03	0.67
OM, % of DM	94.28	93.99	94.26	94.25	0.21
ME,[4] Mcal/kg	2.31	2.31	2.28	2.21	—
CP, % of DM	10.61	11.14	11.93	12.36	0.36
SP, % of CP	31.75	31.55	41.47	40.55	0.33
RUP,[4] % of CP	39.66	45.38	38.66	42.98	—
ADF, % of DM	30.44	29.48	29.52	31.72	0.82
NDF, % of DM	48.72	46.69	46.95	48.39	1.24
TNC,[5] % of DM	26.48	27.04	28.08	26.79	0.92
EE,[5] % of DM	2.5	2.78	2.7	2.95	0.09
P, % of DM	0.3	0.32	0.29	0.3	0.01
Ca, % of DM	0.6	0.7	0.66	0.61	0.05
K, % of DM	1.31	1.32	1.27	1.29	0.02
Mg, % of DM	0.31	0.31	0.31	0.29	0.02

[1]SBM = soybean meal.

[2]Vitamins A, D, and E contained 6,000 KIU of vitamin A, 1,500 KIU of vitamin D, and 37 KIU of vitamin E per kg of DM.

[3]Dairy TM II contained 25.3% Ca, 5.8% S, 303 ppm of Co, 11,111 ppm of Cu, 13,435 ppm of Fe, 909 ppm of I, 20,202 ppm of Mn, and 58,585 ppm of Zn.

[4]Calculated from NRC guidelines (NRC, 2001).

[5]TNC = total nonstructural carbohydrates; EE = ether extract.

Sample Collection and Analysis

Feed and ration samples were composited by period, dried in a forced-air oven at 55°C for 48 h, and ground through a 1-mm screen (Wiley mill; Arthur Thomas, Philadelphia, PA). Period-composited ration samples (experiment 1) or feed samples (experiment 2) were analyzed for DM, ash, and CP (AOAC, 1990), SP (Krishnamoorthy et al., 1983), NDF and ADF (Van Soest et al., 1991), and total nonstructural carbohydrates (Smith, 1981). Analysis of NDF included the use of heat-stable α-amylase and sodium sulfite (Van Soest et al., 1991).