THE RELATIVE VALUE OF RUMINALLY DEGRADABLE AND UNDEGRADABLE PROTEIN ON THE UTILIZATION OF LOW-QUALITY PRAIRIE HAY BY STEERS

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Summary

An experiment was performed to investigate the impact of providing six levels of ruminally degradable protein (RDP; protein that is available to ruminal microbes) in combination with two levels of ruminally undegradable protein (RUP; protein that is not available to the ruminal microbes, but can be digested directly by cattle) on the intake and digestion of low-quality prairie hay. Twelve steers were provided unlimited access to low-quality prairie hay (5.3% crude protein and 71.7% neutral detergent fiber) throughout the trial. To simulate dietary RUP, casein was infused abomasally once daily at either 0 or 0.087% of body weight. To simulate dietary RDP, casein was infused ruminally once daily at 0, 0.029, 0.058, 0.087, 0.116, or 0.145% of body weight. As provision of RDP increased, forage intake and fiber digestion increased. Supplementing with RUP alone increased forage intake but not fiber digestion, although the intake response was not as large as providing the same amount of RDP. In conclusion, RUP is less efficient than RDP in stimulating forage intake and digestion.

Introduction

Low-quality forage typically limits beef production because of its low crude protein content (less than 7% crude protein), which limits the amount of nitrogen available to ruminal microbes. Research at Kansas State University and other research institutions has consistently demonstrated that supplementing low-quality forage with feeds rich in crude protein increases the utilization of the forage resource and improves livestock performance. However, protein can be classified into two broad categories: ruminally degradable protein (RDP; also known as degradable intake protein or DIP) and ruminally undegradable protein (RUP; also known as undegradable intake protein or UIP). Ruminally degradable protein is the fraction of the protein consumed by the animal that has the potential to be degraded by ruminal microbes and subsequently used in the synthesis of microbial crude protein and in the fermentation of carbohydrates. Inadequate RDP decreases microbial protein production and ruminal fermentation; this has the potential to decrease feed intake and ultimately animal performance. Ruminally undegradable protein is the portion of the dietary protein that is not degraded and is available for digestion and absorption in the gastric stomach and intestines only by the host animal, similar to the way protein is available to humans. Even so, the potential exists for nitrogen from the RUP to be recycled to the rumen and used by ruminal microbes.

Typically, the goal of supplementing low-quality forages is to address the deficiency of nitrogen in the rumen, which is accomplished most directly with RDP. However, except for non-protein nitrogen sources such as urea, essentially all supplements and forages contain both RDP and RUP. For example, the protein in tallgrass-prairie hay is about 50% degradable and 50% undegradable, whereas the protein in soybean meal is about 70% degradable and 30% undegradable. Therefore, fed cattle received both RDP and RUP. The objective of this study was to investigate how the provision of RUP might affect the impact of sup-

plemental RDP on the consumption and digestion of low-quality forage offered to steers.

Experimental Procedures

Twelve Angus × Hereford steers (average initial body weight = 796 pounds) with ruminal fistulas were used to evaluate the impact of increasing level of supplemental RDP in combination with one of two levels of supplemental RUP. Provision of supplemental RDP was simulated by ruminally infusing casein. Casein was chosen because of its relatively high protein content (95.3% crude protein) and because it is both highly degradable in the rumen and highly digestible in the intestines. This latter point allowed us to use casein to simulate RUP supplementation without having to confound the experiment by using a different protein source as our RUP source. By infusing casein directly into the abomasum (i.e., postruminal infusion), we bypassed the ruminal microbes and, thereby, simulated the appearance of RUP in the gastric stomach and intestines. The RDP was provided daily at 0, 0.029, 0.058, 0.087, 0.116, and 0.145% of initial body weight. These levels were selected based on previous research conducted at Kansas State University and were expected to significantly increase total digestible organic matter intake (which is a sum of the total amount of feed consumed and digested by the animal, and is a good integrated measure of how a treatment affects forage utilization). The RUP was infused daily postruminally at 0 and 0.087% of initial body weight. The 0.087% level was selected to provide sufficient RUP to elicit a potential effect on total digestible organic matter intake and yet small enough to make abomasal infusions feasible.

Steers were given free-choice access to low-quality, tallgrass-prairie hay (Table 1) throughout the experiment. A two period crossover design was used. Each period of the experiment was divided into five phases: 1) 10-day adaptation to the provision of supplemental protein; 2) 7-day measurement of hay intake and digestibility (with continued provision of supplemental protein); 3) 3-day ruminal sampling period (with continued provision of supplemental protein); 4) 10-day depletion (no treatment infusions were administered, intake measurements continued); 5) 7-day measurement of hay intake (no treatment infusions were administered). Steers received their protein supplements at 6:30 each morning and were fed their hay shortly thereafter. Total fecal collection was used to determine diet digestion. During the 3-day ruminal sampling period a ruminal fermentation profile was conducted to determine ammonia concentrations and ruminal pH.

Table 1. Chemical Composition of Tallgrass-Prairie Hay and Casein

	Tallgrass-Prairie Hay	Casein
	- % of Dry Matter -	
Organic Matter	94.9	96.5
Crude Protein	5.3	95.3
Ruminally Degradable Protein[1]	49.0	-
Neutral Detergent Fiber	71.7	-
Acid Detergent Fiber	46.9	-
Acid Detergent Insoluble Ash	6.8	-

[1]Percent of crude protein.

Results and Discussion

Forage and total digestible organic matter intakes (Table 2) as a percent of initial body weight increased in proportion to the increasing provision of supplemental RDP (linear; $P<0.05$). An interaction between RDP and RUP ($P=0.08$) can be explained by the greater response to supplementation with a low level of RDP when no supplemental RUP was provided. Large increases in intake with the first

increments of RDP were observed when no RUP was provided, but provision of RDP in the presence of supplemental RUP resulted in relatively small increases. This difference in forage and total digestible organic matter intake with RUP supplementation may be explained by the alleviation of a severe nitrogen deficiency via the recycling of RUP, which would render the response to the first increments of RDP supplementation smaller. Increased intake of forage and total digestible organic matter is a commonly observed response when low-quality forage is supplemented with protein. A large portion of this increase can be attributed to the improvement in the amount of nitrogen available to the ruminal microbes.

Supplementing with RUP also increased the total digestible organic matter intake (Table 2; $P<0.05$). The digestion of the organic matter in the supplement itself can account for a portion of this increase. However, a portion of the response was also due to the effect of RUP supplementation on forage intake. When no supplemental RDP was provided, supplementation with RUP increased the intake of forage by about 34%. As noted above, we suspect that some of this increase was due to the recycling of nitrogen to the rumen from the blood of the animal, which would have addressed a portion of the ruminal nitrogen deficiency. However, we observed little difference between these groups in the ruminal events that one would expect to occur (i.e., increased ruminal ammonia and fiber digestion) if nitrogen recycling was solely responsible for the effect on intake. Failure to observe increases in fiber digestion may be the result of increased passage rate (associated with increased intake) masking the effect of nitrogen recycling on fiber digestion. Additionally, small increases in ruminal N supply from recycling may not have been detectable due to rapid utilization by the ruminal microbes in the face of a significant ruminal nitrogen deficiency. Alternatively, RUP may have elicited a more direct effect on the animal's intake control mechanisms. Regardless, as RDP supplementation increased, the positive effect of RUP was less apparent.

When comparing the two treatments that provided the same amount of protein (0.087% of body weight) but in the two different forms (i.e., as RDP or RUP), we observed that the total digestible organic matter intake was increased 77% with RDP supplementation alone but only 50% with RUP supplementation alone. This indicates that RDP supplementation is likely to be more efficient than RUP supplementation at stimulating an overall increase in the intake and digestion of low-quality forage.

Provision of supplemental RDP increased (linear; $P<0.01$) organic matter and forage fiber (i.e., neutral detergent fiber) digestion (Table 3). Such increases in digestion are largely attributable to providing the ruminal microbes with a source of nitrogen. Increased levels of ruminally available nitrogen have been shown to increase ruminal fermentation of low-quality forage. Supplementation with RUP resulted in significant increases ($P<0.01$) in organic matter digestion; however, fiber digestion was not increased. Much of the increase in organic matter digestion in response to RUP is attributable to the digestion of the casein itself. The failure to observe a change in fiber digestion with the provision of supplemental RUP highlights the question posed above regarding the importance of nitrogen recycling versus other modes of action in eliciting the positive effect on forage intake observed for this treatment.

Measurements of ruminal metabolites can provide valuable information regarding how supplements bring about improvements in the utilization of low-quality forage. Ruminal pH is of concern because low pH (less than 6.2) can depress fiber fermentation. The provision of either supplemental RDP or RUP failed to significantly influence ruminal pH and the average ruminal pH was greater than 6.2 for all

treatments (Table 3). In general, low-quality forage consumption has been associated with low levels of ruminal ammonia, which limits microbial activity. Supplementation with RDP increased ruminal ammonia (Table 3) and may explain a large portion of the increase in forage utilization. However, RUP supplementation in this study did not significantly increase ruminal ammonia.

Supplementation of low-quality forages with a large portion of the supplemental protein as RDP should bring about the greatest increases in forage intake and digestion. While the ability of RUP to contribute to increased forage utilization should not be overlooked, protein supplementation to cattle eating low-quality range forage should focus on the delivery of RDP.

Table 2. Effect of Supplemental Ruminally Degradable and Undegradable Protein on Forage Intake and Total Digestible Organic Matter Intake in Beef Steers Fed Low-Quality Prairie Hay

		Intake, % of initial body weight daily	
RDP level[a]	RUP level[b]	Forage	Total Digestible Organic Matter Intake
0	0	1.57	0.66
0.029	0	2.06	0.87
0.058	0	2.21	1.10
0.087	0	2.36	1.17
0.116	0	2.33	1.19
0.145	0	2.19	1.22
0	0.087	2.11	0.99
0.029	0.087	2.13	0.99
0.058	0.087	2.37	1.26
0.087	0.087	2.10	1.14
0.116	0.087	2.45	1.40
0.145	0.087	2.32	1.31
SEM[c]		0.15	0.084
P – values[d]			
RDP: Linear		0.04	<0.01
RDP: Quadratic		0.15	0.17
RDP: Cubic		0.89	0.79
RUP		0.06	<0.01
RDP × RUP		0.08	0.07

[a]Ruminally degradable protein level, crude protein/day expressed as a % of body weight.
[b]Ruminally undegradable protein level, crude protein/day expressed as % of body weight.
[c]For n = 2.
[d]Probability that responses to treatments of the magnitudes observed were due to random chance.

Table 3. Effect of Supplemental Ruminally Degradable and Undegradable Protein on Digestibility and Ruminal Fermentation Characteristics by Steers Consuming Low-Quality Prairie Hay

RDP level[a]	RUP level[b]	Total tract digestibility, %		pH	Ammonia, m*M*
		Organic Matter	Neutral Detergent Fiber		
0	0	44.8	47.1	6.71	0.33
0.029	0	44.4	46.6	6.59	0.52
0.058	0	50.9	53.7	6.53	1.17
0.087	0	50.1	51.9	6.46	2.67
0.116	0	51.6	55.3	6.46	7.78
0.145	0	54.3	55.3	6.48	5.45
0	0.087	47.2	46.5	6.62	0.91
0.029	0.087	46.5	48.5	6.60	1.08
0.058	0.087	53.2	55.2	6.54	2.83
0.087	0.087	52.7	54.4	6.33	3.30
0.116	0.087	55.8	56.2	6.36	6.30
0.145	0.087	53.3	52.6	6.62	6.50
SEM[c]		1.3	1.5	0.093	0.72
P - values[d]					
RDP: Linear		<0.01	<0.01	0.11	< 0.01
RDP: Quadratic		0.27	0.03	0.12	0.28
RDP: Cubic		0.37	0.32	0.28	0.01
RUP		<0.01	0.49	0.49	0.25
RDP × RUP		0.09	0.50	0.43	0.41

[a]Ruminally degradable protein level, crude protein/day expressed as a % of body weight.
[b]Ruminally undegradable protein level, crude protein/day expressed as % of body weight.
[c]For n = 2
[d]Probability that responses to treatments of the magnitudes observed were due to random chance.