Impact of Urea on Corn Silage Growing Cattle Diets

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Summary with Implications

Two experiments were conducted to evaluate the effects of increasing urea in a corn silage growing cattle diet and ensiling time impact on rumen undegradable protein content of corn silage. Four treatments (urea inclusion at 0, 0.5, 1, and 1.5% of diet dry matter) were evaluated in diets containing 95% corn silage using 10 ruminally and duodenally cannulated heifers. Corn silage was sampled 5 times (every 32 days) to determine rumen undegradable protein content. Intake and total tract digestibility of dry matter, organic matter, and neutral detergent fiber all increased linearly with increasing inclusion of urea in the diet. Measured microbial crude protein synthesis was greatest for the 0.5 and 1% urea diets, averaging 15% of TDN. As ensiling time increased, rumen undegradable protein content of the corn silage decreased from 32% of crude protein on the day of corn silage harvest to 17% after 160 days. This was primarily driven by changes in the corn grain in the first 30 days of ensiling as the forage component of the corn silage had little change across time.

Introduction

Estimating the amount of microbial crude protein (MCP) synthesized in the rumen has large implications on diet formulation and estimated metabolizable protein (MP) requirements; especially for those animals that are growing and have a greater requirement for MP as a percentage of dietary dry matter (DM). In addition, growing cattle diets are often formulated to include ingredients such as corn silage, which contain intermediate amounts of fermentable energy and protein, and both forage and grain. This could lead to under- or over-feeding supplemental protein to growing cattle depending on which modeling technique is utilized.

Predicting the amount of rumen undegradable protein (RUP) supplied by corn silage is difficult and can have varying results. In situ techniques have been developed to estimate the RUP content of forages and concentrates; however, corn silage contains forage and grain components which could cause variation in analyses and sampling techniques. In addition, the amount of MCP contributing to MP is dependent on meeting rumen degradable protein requirements (through urea). Therefore, the objectives of this experiment were to estimate the microbial efficiency of diets consisting of 95% corn silage with additional urea and estimate the RUP content of the forage and grain components of corn silage separately to determine the RUP content of corn silage.

Procedure

Experiment 1

Ten ruminally and duodenally cannulated heifers were utilized in a replicated 4 × 4 Latin square digestion experiment with 4 periods and 4 dietary treatments. Four heifers were assigned in each square to one of four treatments for four consecutive 21-d periods. Two additional animals were assigned randomly to treatment in each period for a total of 10 observations per period or 40 observations total. The objective was to evaluate the effects of increasing dietary urea in corn silage-based diets. Four treatments were dietary urea included in the supplement at 0%, 0.5%, 1%, or 1.5% of total dietary DM in diets containing 95% corn silage and 5% supplement (Table 1).

Experimental periods were 21 d in length with the first 16 d of each period used for diet adaptation and d 17 to 21 used for sample collection. Titanium dioxide (5 g) was dosed through the rumen cannula at 0800 and 1700 h daily to determine fecal output in periods 1 and 2 (10 g per day). During periods 3 and 4, 8 g TiO2 was used to move the average sample concentration of marker closer to the center of the standard curve of known standards (16 g per day). On d 17 to 20, fecal grab samples (0.55 lb) and duodenal flow contents (250 mL) were collected four times daily at 0800, 1200, 1400, 1800 h. Whole rumen contents (4.5 lb) were collected at 1600 h (8 h post-feeding) on d 20 of each period to isolate bacterial pellets. Duodenal and bacterial composites were analyzed for purine concentration to determine duodenal flow of MCP.

Experiment 2

The effects of ensiling time on the RUP content of forage and grain components of corn silage were measured utilizing 2 ruminally cannulated steers offered 50% silage, 32.5% Sweet Bran, 15% MDGS, and 2.5% supplement *ad libitum*. Whole corn silage samples (15.4 lbs) were collected at the time of corn silage harvest (d 0) and 32 d, 64 d, 96 d, and 160 d following ensiling after removing approximately 12 in from the face of the ag bag. Fresh corn silage samples were placed in water in order to separate the grain from the forage components of the silage with forage floating to the top and grain sinking to the bottom to be collected separately. After separation and freeze drying, forage samples were ground to pass through a 2-mm screen and the grain samples were left as-is.

Samples of forage and grain (5 g) were weighed into Dacron bags and sealed. Two steers were used for rumen incubation with 2 replications (bags) of each sample per steer. There were 10 experimental samples in total (5 forage and 5 grain samples representing each of the 5 different ensiling duration timepoints). At the time of removal from the rumen, all bags were rinsed in

Table 1. Experimental diets fed to growing cattle in Exp. 1

	Dietary urea inclusion, % of DM			
Item	0	0.5	1	1.5
Ingredient, % DM				
Corn silage	95	95	95	95
Supplement	5	5	5	5
Fine ground corn	3.160	2.660	2.160	1.660
Limestone	1.350	1.350	1.350	1.350
Urea	0.000	0.500	1.000	1.500
Salt	0.300	0.300	0.300	0.300
Tallow	0.125	0.125	0.125	0.125
Beef trace mineral[1]	0.050	0.050	0.050	0.050
Vitamin A-D-E[2]	0.015	0.015	0.015	0.015
Nutrient Content, %DM [3]				
Organic matter	94.46	94.55	94.60	94.57
Neutral detergent fiber	42.44	42.34	42.36	42.27
Crude protein	8.49	9.85	11.21	12.57

[1]Premix formulated to contain 6.0% Zn, 5.0% Fe, 4.0% Mn, 2.0% Cu, 0.29% Mg, 0.2% I, 0.05% Co

[2]Premix formulated to contain Vitamin A—30,000 IU, Vitamin D—6,000 IU, Vitamin E—7.5 IU / g

[3]Based on analyzed nutrients for each ingredient

water and then frozen until analysis. At the time of analysis, forage sample bags were refluxed for 75 min in neutral detergent solution to remove attached microbes. Dry bags were then opened, and the contents analyzed for N to determine RUP content of the samples. Because some of the protein would have been water soluble and therefore was removed from the grain prior to freeze drying, the CP content of the corn grain used in the calculation for RUP was adjusted to the CP of the originating whole corn. The CP content of the corn grain averaged 4.01% after ensiling and after separation in water from the stover components therefore we assume approximately 52% of the corn grain CP in corn silage was water soluble. Grain is assumed to make up 50% of corn silage CP content with the other 50% coming from forage.

Statistical Analysis

Data from the metabolism experiment were analyzed using the MIXED procedure of SAS (SAS ver. 9.4; Inst IN., Cary, NC) with period and treatment as fixed effects and animal serving a random effect. Preplanned orthogonal contrasts for linearly spaced treatments were evaluated.

Rumen undegradable protein content from each of the corn silage components at each of the durations of ensiling were compared using the MIXED procedure of SAS. Corn silage components were modeled separately (forage and grain). Animal served as a random effect. Statistical comparisons were considered significant at $P \leq 0.05$.

Results

Experiment 1

Intake of DM, organic matter (OM), and neutral detergent fiber (NDF) linearly increased ($P < 0.01$) with increasing dietary urea while no differences in excretion were detected ($P \geq 0.18$; Table 2). Apparent total tract digestibility of the nutrients also increased linearly as dietary urea inclusion increased ($P < 0.01$). Diets with only corn silage appeared deficient in rumen degradable protein (RDP) based on the increases in intake and digestibility. True OM digestibility in the rumen increased quadratically ($P = 0.01$) with increasing amounts of urea. Maximum OM digestibility (71.5%) was determined at 0.92% urea inclusion.

A quadratic effect was detected for MCP flow ($P < 0.01$). Based on the first derivative of the quadratic equation, MCP would be maximized at 675 g/d when 0.88% of dietary DM was urea. Urea was included in the supplement of the total mixed ration and not top dressed or infused. This potentially stabilized ruminal ammonia concentrations compared to pulse dosing.

When dietary urea was increased to 0.5% of DM, MCP flow was 666 g MCP/d (measured) compared to 399 and 533 g/d estimated by well-known nutritional models, respectively (Table 3). With increasing urea supplementation, measured MCP flow decreased quadratically while the MCP flow predicted in both modeling techniques increased linearly ($P < 0.05$). When 1.5% urea was added to the diet, MCP flow predicted was not different than measured microbial flow. Estimated TDN intake linearly increased in the current study; however, no other dietary characteristics were changed other than urea. This is important, as these data highlight the need to meet RDP requirements before estimating MCP flow using currently available models.

Microbial efficiency was 15.8% of TDN intake when RDP requirements were met with 0.5 to 1.0% urea inclusion. As 1.5% urea was added to the all-corn silage diets in the study, microbial efficiency was 11.0%. The decreased microbial efficiency in corn silage-based diets may be in part caused by increased ammonia concentrations in the rumen or passage rate.

Experiment 2

The estimated RUP content of whole corn silage decreased with increasing days ensiled (Table 4). The greatest decrease in RUP was between 0 and 32 d of storage, and the average RUP content was 16.1% of CP among samples collected between d 32 and d 160. The largest decrease was in the corn grain component, with less change in the forage component of the corn silage. This change in corn grain RUP is primarily driven by the increase in protein solubility in the corn component of corn silage

Table 2. Effects of urea in corn silage-based diets on nutrient intake and apparent total tract digestibility in Exp. 1

	Dietary urea inclusion, % of DM[1]					Contrast[2]		
Item	0	0.5	1	1.5	SEM	Linear	Quadratic	Cubic
DM								
Intake, lb / d	12.6	13.4	14.1	15.0	0.64	<0.01	0.79	0.85
Digestibility, %	55.8	57.3	59.7	60.8	0.83	<0.01	0.82	0.55
OM								
Intake, lb / d	11.9	12.6	13.2	14.1	0.62	<0.01	0.81	0.86
Digestibility, %	60.1	61.1	63.3	64.9	0.77	<0.01	0.69	0.58
NDF								
Intake, lb / d	5.3	5.7	6.0	6.2	0.26	<0.01	0.92	0.98
Digestibility, %	40.4	43.0	45.4	47.8	1.50	<0.01	0.94	0.99
True OM rumen digestibility, %	56.4	68.1	71.7	65.4	2.99	0.03	0.006	0.90
Microbial Crude Protein flow, g/d	268	666	606	511	71.6	0.04	0.001	0.18
Microbial efficiency, % of TDN	6.9	16.0	13.9	11.0	1.5	0.14	0.001	0.14

[1]Treatments were 0%, 0.5%, 1%, or 1.5% dietary urea included in the supplement of diets containing 95% corn silage and 5% supplement

[2]Orthogonal contrasts

Table 3. Effects of urea inclusion in corn silage-based diets and modeling technique on predicted or measured microbial crude protein (MCP) synthesis in Exp. 1

	Dietary urea inclusion, % of DM[1]					Contrast[2]		
Item	0	0.5	1	1.5	SEM	Linear	Quadratic	Cubic
TDNI, g/d[3]	3,879	4,097	4,299	4,577	197	<0.01	0.79	0.85
MCP synthesis, g/d								
Measured[4]	268	666	606	511	71.6	0.040	<0.01	0.19
BCNRM[5]	380	399	417	441	17.2	<0.01	0.80	0.84
NRC 1996[6]	504	533	559	595	25.6	<0.01	0.79	0.85

[1]Treatments were 0%, 0.5%, 1%, or 1.5% dietary urea included in diets containing 95% corn silage and 5% supplement

[2]Orthogonal contrasts

[3]Total digestible nutrient intake (TDNI); TDN for corn silage assumed as 67.7% of DM

[4]Measured in the current study

[5]Predicted using TDN intake from the current study and equation 6–1 pp. 95 of the 2016 NRC

[6]Predicted using TDN from the current and microbial efficiency of 13% of TDN (NRC, 1996)

associated with prolamin degradation. In many references, the RUP content of corn silage is listed as 25% of CP, which is likely overestimated and can affect diet formulation in high corn silage diets. In addition, previous research suggests only 50% of the RUP in corn silage is digestible. Combined, the digestible RUP content of silage is quite low, suggesting both RDP and RUP supplementation is necessary in corn silage-based diets.

Conclusion

The RUP content of corn silage is reduced as time spent in storage increases. Analyzing the forage and grain components separately resulted in an estimate of 16% of CP as RUP, of which 50% is estimated to be digestible. Corn silage is low in CP and RDP relative to fermentable energy and supplementation of RDP in corn silage-based diets improves digestion.

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Table 4. Main effect of ensiling time on rumen undegradable protein (RUP) content of forage and corn components of corn silage in Exp. 2

	Ensiling time, d						Contrast[1]		
Item	0	32	75	96	160	SEM	Linear	Quad	Cubic
Whole Silage									
DM	39.04	39.82	39.10	39.30	36.20	-	-	-	-
CP, %DM	8.57	9.20	8.72	8.96	9.35	-	-	-	-
RUP, %CP[2]	31.97	16.80	19.91	15.73	17.11	-	-	-	-
Forage[3]									
CP, %DM	7.92	8.79	8.67	7.06	8.33	-	-	-	-
RUP, %CP	20.28	17.81	19.00	21.49	18.06	2.19	0.44	0.28	<0.01
Corn[4]									
CP, %DM[5]	8.57	9.20	8.72	8.96	9.35	-	-	-	-
RUP, %CP	43.65	15.79	10.82	9.96	16.15	2.55	<0.01	<0.01	<0.01

[1]Orthogonal contrasts calculated for unevenly spaced treatments

[2]Estimated as the average of RUP content for the forage and grain components assuming whole silage is 50% corn grain and 50% forage from stover with similar amounts of CP

[3]Forage component of corn silage after being separated from grain in water

[4]Corn grain component of corn silage after being separated from forage in water

[5]Corrected to match the CP of the whole corn silage. Measured CP of corn after washing in water averaged 4.01% of DM due to soluble protein loss in water.