Effects of Forage Maturity on Phosphorus Digestion in Beef Cows

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Kelli Bormann, Graduate Research Assistant
Wendy Powers, Associate Professor of Animal Science
Jim Russell, Professor of Animal Science

Summary and Implications

For environmental reasons, minimizing phosphorus excretion from cattle is of great interest. Current estimates of forage phosphorus digestibility by cattle consider that phosphorus digestibility does not change with composition of the pasture. To better estimate phosphorus (P) excretion, estimates of P digestibility for forages of different compositions are needed. Four crossbred cow/calf pairs were stocked on four pastures managed with grazing (G) or grazing with hay removal (G/H). Forage was maintained in paddocks at 50% removal. Collected pasture samples and fecal samples from cows administered chromic oxide were analyzed for P, NDF, and ADL contents. Rumen evacuations of steers were conducted to evaluate composition of consumed forage for each treatment. Forage analyzed from paddocks where steers grazed demonstrated no grazing management effects on composition, which was evidenced by no differences in composition of rumen contents of the steers. Analysis of the 13th rib bone concludes the cattle were not deficient in phosphorus. Year 1 results suggest that pastures managed under a combination of grazing and initial hay removal resulted in greater P content of the forage and concomitant increased P excretion by cows consuming that forage. There was no treatment effect for P retention, however a there was a date effect with the G treatment having higher P retention in July and September. These results verify that grazing management practices can have a substantial effect on water pollution potential.

Introduction

Pending environmental regulations in Iowa and nationally will restrict the land application of phosphorus in some areas. Phosphorus consumed by cattle is either digested and absorbed or excreted, primarily in feces. By predicting the amount of phosphorus cows are consuming and digesting from a pasture of a given maturity, producers can estimate how much phosphorus is excreted and use these estimates for assessing nutrient management strategies. Studies determining the digestibility of phosphorus contained in forages are limited. Current estimates of forage phosphorus digestibility by beef cattle (National Research Council, 1996) consider that phosphorus digestibility does not change with stage of maturity of the forage. However, in order to better estimate phosphorus (P) excretion, accurate P digestibility coefficients that are specific to stage of hay and pasture maturity are needed. The objective of this study is to determine the apparent digestibility of P for pastures at two different maturities by using a rotational stocking system with and without supplemental hay removal. The two treatments used in this study are 1) grazing (G) and 2) grazing with hay removal (G/H), which could be considered less mature because the cows were grazing the grass much more intensely throughout the grazing period.

Materials and Methods

Four pastures of approximately five acres each were used at the Iowa State University Beef Nutrition Farm in Ames, Iowa. Pasture forage consisted of smooth bromegrass (*Bromus inermis*) predominately. Each pasture was randomly assigned to either a gazing or a grazing/hay pasture management. The grazing/hay treatment was obtained by using a rotational stocking system utilizing 60% of the pasture for hay and 40% for grazing (G/H). This treatment consisted of four paddocks until the re growth after the hay cutting was ready and then the pasture was divided into 10 paddocks. The grazing treatment utilized 100% of a rotational stocking system (G). This treatment consisted of 10 paddocks throughout the entire grazing period. During the first month of the grazing period cows were rotated between paddocks everyday to keep ahead of the forage growth. After the first month, paddocks within each pasture were maintained to 50% forage removal.

Cows

Four groups of four cow-calf pairs were used to evaluate the effects of forage maturity on phosphorus digestion in a grazing system. Cow weight and body condition score of the sixteen crossbred cows was measured and recorded over a two-day period at the beginning of the grazing season, the conclusion of grazing, and every 28 d. Body condition score was measured using a scale of one through nine. A score of one consisted of an extremely emaciated cow and a score of nine considered an obese cow (Boyles, et. al., 1992). Calf weights were measured every 28 d.

Digestibility Trial

During three week-long periods in May, July, and September, an indigestible marker, chromic oxide, was administered to the cows (six g/d) in order to determine mass feces voided. Feces were collected during the last three d of the seven d period. Fecal samples were analyzed for P (A.O.A.C. Total Phosphorus Determination Method #973.56), NDF, ADL (A.O.A.C. Method # 973.18; adapted for use with an instrument ANKOM Technology, Fairport, NY), and chromium content (A.O.A.C. Method # 993.23).

Forage Selectivity Trial

Four fistulated steers were used to determine the forage selection pattern of the cows. Rumen contents of the steers were collected and analyzed in order to determine chemical composition of consumed forage. Rumen evacuations of each steer were performed during four periods throughout summer grazing. Each steer was randomly assigned to a pasture and was allowed to graze with the cows for five d. On day six, the rumens of the steers were completely emptied. Following evacuations, the steers were returned to the pastures to graze for two h. Grab samples of the rumen contents were collected. The rumen was cleaned once again, and the steers were not allowed feed or water for two h. Saliva samples were collected from the rumen and analyzed for total phosphorus content in order to estimate the contribution of salivary phosphorus to total phosphorus ingested. Collected rumen contents were analyzed for P, NDF, and ADL content.

Pasture Composition and Maintenance

Pastures were maintained at 50% forage removal level by using a rising plate meter, 8.8 lbs/yd^2 (4.8 kg/m^2), (Hermann et. al., 2002). Six random measurements were collected in grazed paddocks. An initial height was obtained followed by daily monitoring until 50% of the forage had been removed. Cows were then moved to the next paddock where sward heights were monitored. Following initial hay removal from the G/H treatments, a 30-d re-growth period was allowed before grazing occurred.

Forage samples were clipped every 28 d from each pasture using a hand clipper. A 0.3 yd^2 (0.25 m^2) square made of PVC pipe was tossed randomly twice in each paddock within the pasture. All of the clipped forage from each pasture was compiled into a composite sample from each pasture. The composite sample of the pasture was analyzed for P, NDF, and ADL content.

Concurrent with the composite pasture sampling every 28 d, one 0.3 yd^2 (0.25 m^2) square was hand clipped from each paddock within the pasture and sorted by maturity class (Moore et. al., 1991). Each maturity class was weighed and the stems counted to calculate the percentage that each maturity class represented of the total sample.

During the rumen evacuations, a 0.3 yd^2 (0.25 m^2) square was used to randomly sample the forage within the paddock the steers were grazing. The equivalent of two squares of grass were hand clipped using grass clippers. This grass was sorted by maturity using a maturity chart (Moore et. al., 1991). Each of the maturities was weighed, the stems counted and recorded. All samples were analyzed for P, NDF, and ADL content.

Phosphorus Retention

Using the in vitro dry matter digestibility of the collected rumen content samples (rumen content samples were used to simulate what the animals were actually choosing to eat), forage intake and phosphorus retention of each animal was calculated and compared between treatments using the following equations.

Feces Production (kg) = (Chromium Intake (g)/(Chromium in Feces (%)/100))/1000

Intake (kg) = Feces Production (kg)/(1-Digestibility of Rumen Content Samples)

Phosphorus Intake (g) = (Forage Intake (g) *(Forage Phosphorus (%)/100))*1000

Phosphorus Output (g) = Feces Production (g)*Fecal Phosphorus (%)

Phosphorus Retention (%) = ((Phosphorus Intake (g)-Phosphorus Output (g))/Phosphorus Intake (g))*100

Bone Biopsies

The cows were not supplemented with any phosphorus during the grazing period. Bone phosphorus content can be used as an indicator of P status in the animal (Crenshaw et. al., 1981). Bone biopsies were performed on each cow at the end of the grazing period to assess treatment effects on bone status. Force need to break the bone cleanly was determined. The bones were then de-fatted and analyzed for total phosphorus using the method previously described.

Results and Discussion

Treatment did not have an effect on cow weight (G = 658 kg, G/H = 644 kg; P = 0.4344) or body condition score (G = 5, G/H = 5; P = 0.5683). Also, there was no significant date by treatment interaction (P >0.05).

Treatment differences occurred for P (G = 0.41, G/H = 0.48; P = 0.0087) and dry matter content (DM) (G = 33.97%, G/H = 25.65%; P = 0.0020) in the monthly pasture samples. Dry matter differences may be attributed to greater amounts of dead plant material in the G pastures. No significant treatment differences (P > 0.05) were observed for NDF (G = 63.03%, G/H = 61.95%) or ADL (G = 23.58 %, G/H = 22.86%) content in the pasture samples.

No grazing management effects were observed for composition of the samples clipped from paddocks where steers grazed (Table 1) however, a significant date ×

treatment interaction was observed for P (P < 0.0001) and NDF (P = 0.0002) of the rumen samples. The P content in the G pastures decreased throughout the grazing period (0.47, 0.47, 0.39, and 0.38% for May 22, May 23, July 17 and September 7 sampling dates). The P content of the G/H pastures corresponded to 0.43, 0.45, 0.72, and 0.50% for May 22, May 23, July 17, and September 7 sampling dates, respectively (P < 0.0001; Table 1). The increased P content in July may be attributed to a greater re growth period resulting from less intensive grazing when more paddocks were made available following hay removal.

Table 2 depicts harvest date effects on the chemical compositions of each maturity class from forage samples collected in paddocks grazed by steers. Forage samples collected on July 17 contained less NDF (53.66%) than samples collected in May 22, May 23, and September 7 (62.76, 67.94, and 59.75%, respectively; P < 0.0001). Forage samples collected on July 17 and September 7 contained less ADL (12.91 and 11.54% NDF, respectively) than forages collected on May 22 and May 23 (21.71 and 21.98% NDF, respectively; P < 0.0001). Phosphorus composition differed between maturity classes (P = 0.0353, Table 2). The NDF and ADL contents were not significantly different between classes. No significant treatment or date × maturity interactions were observed for forage composition.

Fecal excretion from cows demonstrated a significant date × treatment interaction for P (P < 0.0001), NDF (P = 0.0005; Table 3). Grazing management effects were significant for P (P < 0.0001) and grams of P excreted (P < 0.0344) with the G/H pasture containing greater P concentration (Table 3). Gazing management did not show an effect on bone breaking strength or bone phosphorus content in cows (G/H = 125 mm of force, G= 117 mm of force, P = 0.7073). Bone P was not significantly different between grazing management practices (G/H = 17.08% P, G = 17.14% P; P = 0.8462).

Treatment did not have an effect on P (0.62%), NDF (46.2%), ADL (12.56%), or saliva P (1.38%) composition of rumen contents (P > 0.05). Using only one steer per pasture provided limited degrees of freedom when analyzing these data. While the data tends to show differences, there were insufficient observations to demonstrate significance.

Treatment did not show an effect for phosphorus retention, however there was a significant date effect (P = 0.0002) and a date x treatment interaction (P < 0.0001), with the cattle on the grazing treatment having greater phosphorus retention in the months of July and September (July: 27% G; 14% G/H and September: 37% G; 18% G/H). The cattle on the G treatment showed a date effect for forage intake (P < 0.0001) and a treatment effect for fecal phosphorus (P < 0.0001). The cows on the G treatment had a mean excretion of phosphorus of 1.03% and the G/H treatment had a mean fecal phosphorus concentration of 1.24%. These factors show the cattle on G treatment retained more phosphorus over the course of the summer.

Overall the cows on the G/H treatment had greater P excretion and lower P retention in months when the P content of the forage was statistically higher than the G treatment. In July the cows on the G/H treatment excreted on average 82 g of P, with cows on the G treatment excreting 101 g of P. Cattle on the G treatment excreted 20% less P than cattle on pastures with supplemental hay removal. This study indicates that pasture and grazing management can play a large role in the water pollution potential of individual farms.

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References

Boyles, S. 1992. Cow nutrition and body condition. Bulletin AS-1026. NDSU. Fargo.

Crenshaw, T.D., E.R. Peo, Jr., A.J. Lewis, and B.D. Moser.1981. Bone strength as a trait for assessing mineralization in swine; A critical review of techniques involved. J.Anim.Sci. 53:827-835.

Hermann, M.L., J.R. Russell, and S.K. Barnhart. 2002. Evaluation of hay-type and grazing-tolerant alfalfa cultivars in season-long or complementary rotational stocking systems for beef cows. J.Anim.Sci. 80:768-779.

Moore, K.J., L.E. Moser, K.P. Vogel, S.S. Waller, B.E. Johnson and J.F. Pedersen. 1991. Describing and quantifying growth stages of perennial forage grasses. Agronomy Journal. 83:1073-1077.

National Research Council. Nutrient Requirements of Beef Cattle.1996. National Academy Press.

Official Methods of Analysis. A.O.A.C. International. Gaithersburg, MD. 2001. 16th edition.

Table 1. Paddock composition clipped during rumen evacuations from each pasture under one of two management systems.

	P, %	NDF, %	ADL, % NDF		P, %	NDF, %	ADL, % NDF
Grazing/Hay				Grazing			
5/22/02	0.43	64.73	22.03	5/22/02	0.47	60.72	21.59
5/23/02	0.45	68.48	23.04	5/23/02	0.47	67.17	21.70
7/17/02	0.72	48.42	12.76	7/17/02	0.39	53.63	13.20
9/7/02	0.50	59.53	12.52	9/7/02	0.38	61.71	11.89
P-value	<0.0001	0.0002	0.4387	P-value	<0.0001	0.0002	0.4387

Table 2. Composition of maturity classes sorted from forage samples clipped during rumen evacuations from paddocks in pastures under one of two management systems.

Class[a,b]	VO	V1	V2	V3	E0	E1	E2	E3	R0	R1	Other
5/22/02											
P, %	--	0.39	0.44	0.44	--	0.55	0.40	0.42	0.42	0.39	0.40
NDF, %	66.57	64.8	60.86	62.71	--	59.71	61.7	60.25	65.60	64.15	61.24
ADL,% NDF	26.26	22.39	20.81	20.80	--	17.24	21.76	22.28	25.25	21.07	19.87
%by mass	0. 2	2.0	6.0	13.0	--	24.0	27.0	20.0	18.0	21.0	9.0
5/23/02											
P, %	--	--	0.36	0.49	--	--	0.42	0.44	--	0.40	0.37
NDF, %	--	71.41	69.16	65.15	--	--	68.60	65.31	--	71.33	64.68
ADL,% NDF	--	23.47	23.18	20.57	--	--	22.62	21.18	--	21.89	20.95
%by mass	--	-0.6	0.9	4.5	--	--	17.8	27.0	--	41.0	10.0
7/17/02											
P, %	0.76	0.71	0.68	0.59	0.53	0.33	0.31	0.32	--	--	0.48
NDF, %	48.28	48.39	69.16	48.57	52.86	53.21	54.82	55.33	--	--	52.38
ADL,% NDF	13.67	12.70	11.44	13.16	13.41	13.46	12.77	12.65	--	--	12.95
%by mass	6.0	12.0	30.0	12.0	6.0	4.0	30.0	12.0	--	--	16.0
9/7/02											
P, %	--	--	--	0.32	--	0.37	--	0.47	0.53	--	0.29
NDF, %	--	--	--	60.14	--	61.51	58.08	57.71	58.30	--	62.79
ADL,% NDF	--	--	--	11.55	--	12.75	8.58	11.24	13.10	--	11.99
%by mass	--	--	--	29.0	--	23.0	4.0	16.0	13.0	--	29.0

[a]Maturity classes as described by Moore et. al., 1991.
V= vegetative stage of growth
E= elongation stage of growth
R= reproductive stage of growth
Each number represents a subset of the stage of growth
The other category was for weeds, dead material, and unidentifiable parts.

[b]Samples are pooled across grazing management practice (P > 0.05 for % P, % NDF). Sampling date was significant for % NDF (P < 0.0001). Maturity class was significant for % P (P = 0.0353).

Table 3. Composition of fecal excretion from cows grazing pastures managed under one of two management systems.

	P, %	NDF, %	ADL, % NDF
Grazing/Hay			
5/16/02	1.30	58.79	27.16
7/11/02	1.43	45.52	8.8
9/5/02	0.97	50.10	13.67
Grazing			
5/16/02	1.26	56.96	26.65
7/11/02	0.86	50.55	9.9
9/5/02	0.97	48.39	13.85
Pooled by Date			
Grazing/Hay	1.24	51.47	16.54
Grazing	1.03	51.97	16.81
P-value			
Treatment	<0.0001	0.5070	0.5620
Treatment × Date	<0.0001	0.0005	0.3536