THE IMPACT OF NUTRITIONAL FACTORS ON THE DEVELOPMENT OF PHOSPHATIC UROLITHS USING MEAT GOATS AS A MODEL FOR CAPTIVE GIRAFFES

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Abstract

Obstructive urolithiasis is a documented problem in domestic ruminants, such as the meat goat, and exotic herbivores, such as captive giraffe. These two species develop phosphorus based uroliths and are considered browsing ruminants. Due to the logistical challenges of performing studies with captive giraffe, a metabolic trial was conducted using meat goats as a model. The intent of this study was to determine the impact of type of diet (ADF-16 or Wild Herbivore complete pelleted feed) and complete pelleted feed to hay ratios (20 or 80% hay) on the development of urolithiasis in meat goats, in the context of captive giraffe feeding practices. The diet in which ADF-16 pellets were fed in combination with 20% hay had the lowest levels of fiber, the lowest calcium (Ca) to phosphorus (P) ratio, and the highest level of P compared to the other 3 diet treatments. From our results, we concluded that feeding the ADF-16 pellets with hay as 20% of the diet, produced a trend of high urinary P over the four week experimental period. There was also a tendency for a higher crystal count in the urine when hay was 20% of the diet. These can be considered strong risk factors for the development of phosphatic uroliths and warrants further investigation.

Introduction

A survey of the health history, feeding practices, and dietary content in captive giraffes in North America was conducted in 2004 to examine the possible connection between diet and the development of urolithiasis.[17] There appeared to be a positive correlation between diet and physiologic P levels in giraffe. This may be related to the ratio of concentrate to hay eaten and the nutrient composition of the concentrate.

While giraffes in the wild are considered concentrate selectors (feeding mainly on browse), giraffes in captivity in North American zoos have been shown to be fed mainly pelleted concentrate with variable amounts of alfalfa hay and minimal amounts of browse.[17] Goats are also considered browsing ruminants though far less selective than giraffes.[6,16] Goats of various breeds have been documented with urolithic stone problems in captivity.[3,5,15,19] Obstructive urolithiasis is a condition in which mineral concretions develop and aggregate in the urinary tract. If the stones become too numerous or too large, they may cause obstruction, particularly in castrated male ruminants.[11] This can rapidly progress to bladder or urethral rupture, uremic crisis, and death.[2] The predominant chemical compositions of both goat and giraffe uroliths have been reported to consist of magnesium ammonium phosphate (commonly called struvite) or calcium magnesium phosphate, often with a combination of the two.[3,4,10,12,19,21] These stones often occur when a mainly concentrate diet is presented, with a high phosphorus (P) content.[3,12,19] The high P content can lead to an imbalance of calcium (Ca):P in the serum, which is recommended to be between 2:1 to 4:1 for meat goats.[8] Giraffe have been found to have similar problems with obstructive urolithiasis, including reversed Ca:P in the serum in captivity. Within the last 10 years, seven giraffe have had phosphatic urolithiasis reported as a cause of death.[21] Reversed Ca:P ratios in the serum have been reported as low as 0.53:1.[13] The average serum Ca and P levels in captive giraffe have been reported as 8.0 ± 0.8 and 10.5 ± 2.9 mg/dl, respectively.[7]

In May of 2005, a group of scientists knowledgeable in domestic ruminant nutrition and captive giraffe management met to discuss and establish new feeding guidelines for captive giraffe.[14] They created recommendations regarding the composition of giraffe diets, in terms of decreasing starch and simple sugar content, protein content, P content, and increasing fiber. A new complete pelleted feed for wild herbivores was formulated by Mazuri PMI, based on these recommendations. The objective of the present study was to compare this revised diet to the most prevalently fed commercial diet fed to captive giraffe in North America using goats as a model. In addition, effects of differing complete pelleted feed to hay ratios on the formation of urolithic compounds, urinary pH and P balance were evaluated. We hypothesized that high P content in the diet and a high level of concentrate feeding would increase indicators of urolith formation, including crystal formation and high urinary Ca and P content.

Materials and Methods

The experiment was a randomized complete block design with 16 growing Boer-cross male uncastrated goats, all under one year of age, randomly assigned to one of four treatments in four replicates blocked by weight (n=16) with a fifth, partial replicate composed of two animals as potential replacements (starting weight was 23.5 kg $\pm$ 4.0 kg). Treatments (Table 1) were arranged in a two by two factorial design. Factors consisted of diet (two types of Mazuri PMI brand complete pelleted concentrates, ADF-16 and Wild Herbivore (WH)) and two diet to hay ratios (20% alfalfa hay fed with 80% complete pelleted feed and 80% alfalfa hay fed with 20% complete pelleted feed). During two weeks of standardization, the goats were adjusted gradually to their diets. In order to ensure the proper ratios, the goats were fed at a rate of 115% of their previous day's intake. There were two experimental periods of two weeks, with a seven day adjustment, two day harness adjustment, followed by a five day total fecal and urine collection. On the first and third day of the two collection periods, a fresh sample of urine was collected and examined for pH and crystal content. The number of individual crystals present in one microscopic frame was counted and each frame was also scored on a one to five basis; one being few to no crystals, and five being a frame entirely covered in crystals unable to be quantified. Serum samples were taken from each animal on the day the animals arrived and on the last day of each collection period. A total of 97 samples of hay, complete pelleted feed and feces were ground and measured for Ca, P and magnesium (Mg). Urine samples were analyzed for a urinary electrolyte and mineral panel (Cornell Veterinary Diagnostic Laboratory, Ithaca, NY).

All data were analyzed by ANOVA using Proc GLM and Proc Mixed of SAS (Cary, NC). Treatment main effects and their interactions, replicate, and collection time were compared using

Proc Mixed for nutrient digestibility, retention, and all urine concentrations using the PDIFF option of the least significant difference test when the model was significant ($P \leq 0.05$).

Results and Discussion

The intentions of choosing the hay to pellet ratios used was to reproduce the possible diets that would be given to captive giraffe in zoos.[17] The Ca:P ranged from 1.6:1 in the ADF-16 with 20% hay diet to between 3:1 and 5:1 in the other diets (Table 1). These high ratios are likely due to the relatively high levels of Ca in combination with low P in the alfalfa hay used. The treatments using WH had higher levels of NDF, ADF, cellulose and Mg, with the greatest levels of these nutrients in the 20% hay with 80% WH complete pelleted feed combination.

Bucks fed ADF-16 with 20% hay had the highest intake of P, the highest excretion of P in feces and urine, and the highest P balance ($P < 0.05$; Table 2). There were no significant differences between treatments for P digestibility or retention. The increase in P balance may be explained by the change in P homeostasis involved with high levels of complete pelleted feed, and a low Ca:P ratio. The treatment with ADF-16 and hay as 20% of the diet had the highest level of P (0.6% of the diet) versus the other three treatments (0.3% of the diet). The dietary requirement for 30 kg goats growing 150 g per day for P is 2.8 g/d, or 0.25% of DM intake.[9] This would indicate that the levels of P which the goats were receiving on any treatment were above their requirements. Most of P is excreted in the feces.[18,20] A high level of P will lead to excess P being excreted into the urine, which may explain why the treatment with the highest dietary P level also has a higher excretion of urinary P. Overall for Ca, bucks fed ADF-16 with hay at 20% of the diet had lower Ca intake and lower Ca excretion in feces and urine compared to other treatments ($P < 0.05$); however, digestibility and retention were not different across treatments (Table 2). The ADF-16 pellet fed with hay as 20% of the diet was the only treatment with a Ca:P of less then two to one (Table 1). Animals given lower ratios and lower overall levels of Ca, with relatively higher levels of P, would be expected to excrete less Ca and more P in the urine. When hay was 20% of the diet and the WH diet was fed, bucks had higher Mg intake, fecal Mg, urine Mg, and Mg balance ($P < 0.05$). Mg digestibility was higher when hay was 20% of the diet ($P < 0.05$).

Urinary mineral concentrations (data are shown for P only) were affected by dietary treatments, although urinary creatinine was not. A lack of difference in urine creatinine indicated that dehydration was not a factor. Urinary Ca was higher in goats fed WH complete pelleted feed with hay as 20% of the diet ($P < 0.05$) compared to goats fed ADF-16 complete pelleted feed with hay as 20% of the diet. This was not significant when urinary Ca was standardized for creatinine. Urinary Mg was highest in goats fed WH complete pelleted feed with hay as 20% of the diet ($P < 0.05$) compared with the other three treatments. This remained true once Mg was standardized for creatinine. Standardized urinary P increased when goats were fed ADF-16 with hay as 20% of the diet (Table 3), which is consistent with the increased P excretion in urine we observed for this diet. Urine with high P concentration could predispose animals for stone formation.

A majority of the crystals counted were visually identified as calcium phosphate with few identified as magnesium ammonium phosphate. Crystal score tended to be higher when hay was

20% of the diet compared to when hay was 80% of the diet (Table 3). This trend agreed with the initial hypothesis that high concentrate to hay ratios would increase the amount of urolith precursors. The number of crystals increased for all treatments from the first collection to the second collection. The standard error for these values was quite large, explaining why statistically significant differences were not observed, in spite of relatively large numerical differences (Figure 1). While type of diet alone did not appear to affect crystal formation, the highest values of crystal count and score were seen when ADF-16 diet was fed with hay as 20% of the diet. Urine pH was higher for the animals fed a high level of hay and for the animals fed the WH complete pelleted feed ($P < 0.05$; Table 3). However, all goats had a urinary pH between eight and nine, which is considered to be alkaline. An alkaline urinary pH is conducive to the development of magnesium ammonium phosphate and calcium phosphate uroliths.[1]

Ideas for future studies would include feeding diets for a longer time period, exceeding the 56 day minimum for uroliths to occur,[12] and to test how indicative crystal formation is for actual formation of uroliths. In addition, diets that are more consistent in content, only differing in P, should be studied to determine a problem threshold value for P. Obstructive urolithiasis remains an often deadly problem for goats and giraffes. The solution involves understanding and demonstrating the proper balance of minerals and nutrients in their diets, while mitigating environmental factors, to minimize the risk of this disease.

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Table 1: Nutritional content including neutral detergent fiber (NDF), acid detergent fiber (ADF), crude protein (CP), calcium (Ca), phosphorus (P), and magnesium (Mg) of 4 dietary treatments on a dry matter basis for 18 male uncastrated Boer- cross meat goats.

	ADF-16		Wild Herbivore	
Hay as % of diet:	Hay = 20 %	Hay = 80 %	Hay = 20 %	Hay = 80 %
DM %	90.7	90.4	91.3	90.5
Ash %	8.6	9.7	8.5	9.7
NDF %	32.8	41.1	52.3	46.0
ADF %	17.9	26.4	34.6	30.6
Cellulose %	13.8	20.5	30.8	24.8
CP %	19.5	20.1	15.4	19.0
Ca %	0.96	1.33	1.07	1.36
P %	0.60	0.32	0.35	0.26
Mg %	0.35	0.37	0.42	0.39
Ca:P	1.60	4.16	3.06	5.23

Table 2: Balance of phosphorus, calcium, and magnesium for 18 male uncastrated Boer-cross goats fed one of four diets during two one week collection periods (data are presented as an average of the two periods).

	ADF-16[2]		Wild Herbivore			
	Hay = 20	Hay = 80	Hay = 20	Hay = 80	SEM	P-value[1]
Phosphorus						
Intake (g/d)	7.90	4.02	5.42	3.04	0.30	H D H*D
Fecal (g/d)	4.85	2.48	3.26	1.64	0.31	H D
Urinary (g/d)	0.103	0.002	0.001	0.007	0.03	NS
Balance (g/d)	2.95	1.54	2.16	1.39	0.28	H D
Digestibility %	38.4	37.7	36.8	44.1	5.70	NS
Retention %	37.7	37.8	36.8	44.8	5.53	NS
Calcium						
Intake (g/d)	12.5	15.7	16.1	15.3	1.02	H*D
Fecal (g/d)	9.2	12.3	11.8	11.8	1.00	H*D
Urinary (g/d)	0.10	0.15	0.16	0.13	0.02	H*D
Balance (g/d)	3.20	3.25	4.15	3.34	0.65	P
Digestibility %	26.2	19.8	22.9	20.8	4.05	NS
Retention %	25.7	19.2	22.4	20.4	4.13	NS
Magnesium						
Intake (g/d)	4.61	4.43	6.40	4.38	0.31	H D H*D
Fecal (g/d)	2.61	2.70	3.45	2.58	0.24	D H*D
Urinary (g/d)	1.00	0.85	1.32	0.74	0.09	H H*D
Balance (g/d)	1.01	0.89	1.63	1.07	0.21	H D
Digestibility %	43.4	36.5	43.5	39.3	3.40	H
Retention %	32.7	27.5	33.7	31.1	3.77	NS

[1] $P < 0.05$

H = main effect of hay to complete pelleted feed ratio; D = main effect of type of complete pelleted feed; H*D = interaction between hay to complete pelleted feed ratio and type of complete pelleted feed; P = main effect of collection period; NS = not significant

[2] ADF = Acid Detergent Fiber

Table 3: Urinary phosphorus (P) excretion standardized for creatinine, average urinary crystal score and counts, and urine pH for 18 male uncastrated Boer- cross goats fed one of 4 diets during 2 one week collection periods.

	ADF-16[3]		Wild Herbivore			
	Hay = 20	Hay = 80	Hay = 20	Hay = 80	SEM	P-value
Urinary P:Creatinine (mg/mg)						
Collection 1	0.30[a]	0.01[b]	0.01[b]	0.03[b]		
Collection 2	0.46[c]	0.01[b]	0.03[b]	0.05[b]		
Mean	0.38	0.01	0.02	0.04	0.07	P[1] H[1] D[1] H*D[1] P*H*D[2]
Crystal Score (1-5)						
Collection 1	2.80	1.51	2.20	1.76		
Collection 2	3.10	1.98	2.40	2.33		
Mean	2.75	1.75	2.30	2.04	0.54	H[2]
Number of Crystals Counted						
Collection 1	133	13	104	44		
Collection 2	279	84	196	229		
Mean	206	49	150	137	84.4	P[1]
Average Urine pH						
Collection 1	8.51	8.67	8.83	8.96		
Collection 2	8.37	8.51	8.63	8.88		
Mean	8.44	8.59	8.73	8.92	0.12	H[1] D[1]

[abc] Means without a common superscript differ ($P < 0.05$).

[1] $P < 0.05$

[2] $P < 0.07$

H = main effect of hay to complete pelleted feed ratio; D = main effect of type of complete pelleted feed; H*D = interaction between hay to complete pelleted feed ratio and type of complete pelleted feed; P = main effect of collection period; P*H*D = interaction between period, hay to complete pelleted feed ratio and type of complete pelleted feed; NS = not significant

[3] ADF = Acid detergent fiber

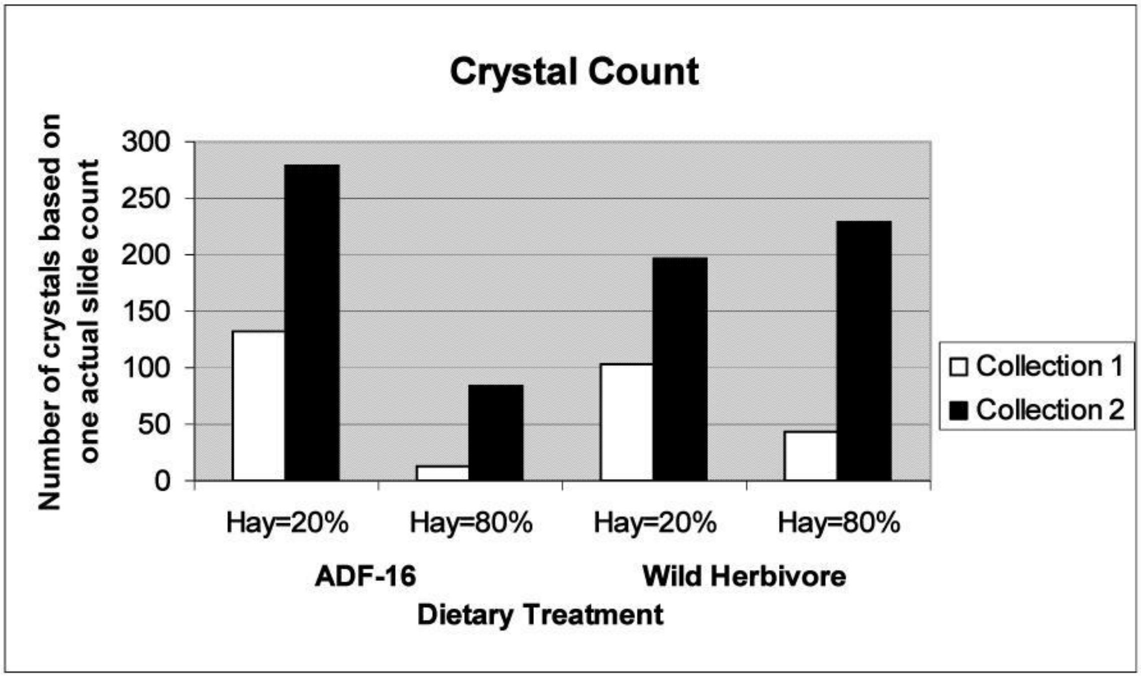

Figure 1: Average urinary crystal count during two collection periods for 18 male uncastrated Boer- cross goats fed one of four diets. ADF = Acid detergent fiber.