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Effects of Supplemental Cobalt on Nutrient Digestion and Nitrogen Balance in Lambs Fed Forage-based Diets

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Summary

The objective of this study was to determine the effects of supplemental cobalt on nutrient digestion and nitrogen balance in lambs fed a forage-based diet. Sixteen wether lambs (initial BW = 28.6 ± 1.3 kg) were used in a two-period crossover design and randomly allotted to one of two treatments being ad libitum grass hay (7.1 percent CP, 68.5 percent NDF, DM basis) plus 45.0 g of dried distillers grains with a commercial mineral formulated to provide 1.1 mg/d of cobalt (CONTROL) in the form of cobalt carbonate or a commercial mineral containing supranutritional levels of cobalt carbonate providing 7.1 mg/d of Cobalt (COBALT). Experimental periods were 21 d in length and consisted of 15 d for diet adaptation and 6 d of total fecal and urine collection. Forage DM, OM, and NDF intake tended to increase ($P = 0.091$) when lambs consumed COBALT. Despite increased forage intake; fecal DM, OM, and NDF flow ($P \geq 0.654$) did not differ between cobalt levels. Total tract DM, OM, and NDF digestibility (percent of total intake) did not differ ($P \geq 0.591$) between CONTROL and COBALT. No differences were observed between cobalt levels for total N intake ($P = 0.129$), total tract N digested (g/d; $P = 0.135$), or urine N output ($P = 0.812$). The provision of additional cobalt to lambs did not increase ($P = 0.251$) N retention. Providing lambs a forage-based diet containing 7.1 mg/d of cobalt tended to increase forage intake but did not affect total tract digestibility or N balance.

Key Words: Cobalt; Digestion; Lamb; Nitrogen Balance

Introduction

Supplementing a forage-based diet with Co may be useful due to the higher ruminal B12 production observed with high-forage diets (forage:concentrate ratio = 100:1) compared to a relatively higher concentrate (40:60) diets (Sutton and Elliot, 1972). Adding supplemental Co to a high-concentrate diet formulated to be deficient in Co increased ruminal propionate production in beef steers (Tiffany et al., 2002). Eskeland et al. (1974) reported an improvement in lamb N balance when propionate was intravenously infused.

Gall et al. (1949) suggested that the digestibility of a diet decreases through bacterial changes when Co is deficient. Lopez-Guisa and Satter (1992) reported that supplementing Co and Cu above the NRC (1989) recommendations increased *in situ* digestibility of low-quality forages. However, literature on the effects of high levels of supplemental organic Co *in vivo* is currently unavailable. Therefore, our hypothesis was that nutrient digestibility and N balance would be altered when supplemental organic cobalt was fed to growing lambs consuming low-quality forages. The objectives of this study were to evaluate the effects of supplemental Co on diet digestibility and N balance in lambs consuming chopped grass hay.

Materials and Methods

Sixteen western, white-face Rambouillet wether lambs (initial body weight = 28.6 kg ± 1.3 kg) were used to evaluate the effect of supplemental organic Co on N balance and total tract digestibility of a forage-based diet. Lambs were randomly allotted to treatment and were placed in individual stainless steel crates housed in a temperature controlled barn (22 °C) with continuous lighting. All lambs were offered chopped (5.1 cm) grass hay (7.1 percent CP and 68.5 percent Neutral Detergent Fiber, DM basis) at 105 percent of the previous days forage intake. In addition, lambs received either 45.0 g (as fed) dried distillers grains that contained a commercial mineral (Bullseye all purpose mineral, Ralco Nutrition Inc., Marshall, Minn., USA) formulated to provide 1.1 mg/d of Co (CONTROL) or the same commercial mineral, which included a highly digestible proprietary form of organic Co (Bullseye all purpose mineral plus CoMax 100, Ralco Nutrition Inc., Marshall, Minn., USA) formulated to provide 7.1 mg/d of Co (COBALT). The experiment was set up as a two-period, switch-back design so that each lamb received each treatment. Each experimental period lasted 21 days with 15 days for diet adaptation and 6 days for sample collection. Lambs were removed from crates and allowed to exercise for four days between experimental periods. All procedures were approved by the Northern Great Plains Research Laboratory Animal Care and Use Committee.

Total urine and fecal output was collected at 0800 on days16 through day 21 of each period. Fecal samples were weighed and a 10-percent subsample was collected each day and composited per animal for each collection period and immediately placed in a 55°C oven. Urine collection vessels contained 30 mL 50 percent HCl (16 M) to maintain urine pH < 3.0 in order to minimize microbial growth and NH3 volatilization. Dried feed, orts, and feces were ground through a 1 mm screen (Wiley mill; Thomas Hill and Sons, Philadelphia, Pa.) and analyzed for DM, ash (AOAC, 1990) and neutral detergent fiber (ANKOM Technologies, Fairport, N.Y.) as described by Vogel et al. (1999). Feed, feces, and urine were analyzed for N by combustion (CE Elantech, Lakewood, N.J.). Cobalt concentrations in feeds were determined by digesting samples in nitric acid and assaying for Co content by inductively coupled plasma optical emission spectrometry (Ultima 2, Horiba Scientific, Kyoto, Japan). Nutrient analysis of hay and supplements are presented in Table 1.

All data were analyzed as a two-period, crossover design using the MIXED model of SAS (SAS, Inst., Cary, N.C.). Level of significance set at $P \leq 0.05$. The model included period and cobalt level, with animal as the random variable. Due to reasons unrelated to treatment, one lamb was removed from the experiment during period 1 and one lamb was removed from the experiment during period 2.

Results and Discussion

Forage DM, OM, and NDF intake increased ($P \leq 0.091$) when lambs consumed 7.1 mg/d of Co (Table 2). Likewise total dietary intake was greater ($P = 0.093$) for lambs fed Co. The provision of additional Co to lambs did not ($P \geq 0.654$) influence fecal excretion of DM, OM, or NDF. Total tract DM, OM, and NDF digestion increased for lambs fed COBALT ($P \leq 0.098$). Nevertheless, total tract digestibility of DM, OM, and NDF (percent of intake) did not differ ($P \geq 0.591$) between cobalt levels (Table 2).

Forage N intake tended ($P = 0.107$) to increase when lambs were fed COBALT. However, total N intake ($P = 0.129$) did not differ across treatments. In addition, fecal N excretion was not different ($P = 0.901$) between cobalt levels. Therefore, no differences were observed between cobalt levels for total tract N digested (g/day; $P = 0.135$) or digestibility (percent of N intake; $P = 0.596$). Urine N output was not influenced ($P = 0.812$) by additional Co and averaged 4.03 g/day.

Table 1. Nutrient composition of ingredients.

Item	Hay	Supplements[a] CONTROL	COBALT
DM	90.0	86.9	86.1
OM (percent of DM)	90.2	94.1	93.4
CP (percent of DM)	7.1	32.5	32.4
NDF (percent of DM)	67.9	55.1	55.8
Cobalt (mg/kg DM)	< 0.2	29.2	183.0

[a] CONTROL = Ad libitum intake of grass hay (7.1 percent CP, 68.5 percent NDF, DM basis) plus 45 g (as fed) dried distillers grains plus Bullseye mineral added in order to provide 1.1 mg/d of cobalt; COBALT = Ad libitum intake of grass hay plus 45 g (as fed) dried distillers grains containing Bullseye mineral™ plus CoMax 100™ added to provide 7.1 mg/d of Cobalt.

Table 2. Influence of supplemental organic cobalt on intake, fecal flow, and digestion of DM, OM, and NDF when wethers were fed forage-based diets.

	Cobalt levels[a]			
Item	**Control**	**Cobalt**	**SEM[b]**	***P* < 0.05**
DM Intake (g/day)				
Forage	844	883	42.6	0.091
Total	882	922	42.6	0.093
OM Intake (g/day)				
Forage	761	798	38.5	0.086
Total	798	834	38.5	0.091
NDF Intake (g/day)				
Forage	577	606	29.3	0.079
Total	599	628	29.3	0.078
Fecal excretion (g/day)				
DM	198	200	8.7	0.818
OM	163	164	7.2	0.819
NDF	140	142	6.5	0.654
Total tract digested (g/day)				
DM	684	721	36.3	0.098
OM	634	670	33.3	0.091
NDF	459	486	24.6	0.097
Total tract digestibility (percent of intake)				
DM	77.5	78.0	0.60	0.591
OM	79.6	80.0	0.58	0.602
NDF	77.1	76.8	0.68	0.732

[a] CONTROL = Ad libitum intake of grass hay (7.1 percent CP, 68.5 percent NDF, DM basis) plus 45 g (as fed) dried distillers grains plus Bullseye mineral added in order to provide 1.1 mg/d of cobalt; COBALT = Ad libitum intake of grass hay plus 45 g (as fed) dried distillers grains containing Bullseye mineral™ plus CoMax 100™ added to provide 7.1 mg/d of Cobalt.
[b] Control n = 14; Cobalt n = 15.

Nitrogen retention expressed as g/day, percent of N intake, or percent of N digested was not different ($P \geq 0.251$) when lambs fed chopped hay were supplemented with Co.

In normal production systems, lambs of this weight would likely not receive low-quality forage. However, it was of interest to determine ways to improve the digestibility of medium- to low-quality hay (7.1 percent CP and 68.5 percent NDF, DM basis). This is important because of the increased cost of finishing lambs due to high grain prices and the desire of some segments of the lamb finishing industry to grow lambs for a longer period of time for backgrounding on grass and/or for grass-fed markets (Held, 2005). Dried distiller's grains were used only as a carrier for the mineral supplements. Based on post-experiment laboratory analysis, CONTROL and COBALT diets provided lambs with 1.2 mg and 8.0 mg Co /kg of DM, respectively. The Co requirements for lambs, as suggested by the NRC (2007), are 0.1 mg to 0.2 mg Co/kg of DM to meet Co requirements and 0.5 mg to 1.0 mg Co/ kg of DM for optimal microbial growth. Previous work in beef cattle (Tiffany and Spears, 2005) fed high-concentrate diets that were marginally deficient in Co noted an increase in DM intake when Co was added to the diet at 0 mg, 0.05 mg, and 0.15 mg/kg of DM. Furthermore, Schwarz et al. (2000) reported an increase in intake when beef bulls were fed diets that exceeded NRC (1996) requirements for Co.

Although there was an increase in dietary DM intake with Co supplementation, the concomitant increase in total tract DM, OM, and NDF digested (g/d) and lack of differences in fecal nutrient flow (g/d) led to no differences being observed in total tract digestibility of DM, OM or NDF. An increase in DM intake accompanied with no change in total tract digestibility, as reported herein, has been well documented previously (reviewed by Galyean and Owens, 1991). This response was likely due to changes in rumen kinetics. Specifically, the tendency for forage intake to increase may have been due to an improvement in ruminal digestibility with Co supplementation (Lopez-Guisa,

Table 3. Influence of supplemental organic cobalt on N intake, N excretion, and N balance in wethers fed forage-based diets.

	Cobalt levels[a]			
Item	**Control**	**Cobalt**	**SEM[b]**	***P* < 0.05**
N Intake (g/day)				
Forage	9.54	9.95	0.48	0.107
Total	11.60	12.00	0.48	0.129
Fecal N excretion (g/day)	2.76	2.77	0.11	0.901
Total tract N digested (g/day)	8.80	9.19	0.40	0.135
Total tract N digestibility (percent of intake)	76.20	76.60	0.64	0.596
Urine N (g/day)	4.01	4.06	0.17	0.812
Total N excreted (g/day)	6.70	6.80	0.24	0.782
Total N retention (g/day)	4.79	5.13	0.34	0.251
N retention (percent N intake)	41.20	41.70	1.60	0.818
N retention (percent N digested)	54.20	54.30	2.00	0.948

[a] CONTROL = Ad libitum intake of grass hay (7.1 percent CP, 68.5 percent NDF, DM basis) plus 45 g (as fed) dried distillers grains plus Bullseye mineral added in order to provide 1.1 mg/d of cobalt; COBALT = Ad libitum intake of grass hay plus 45 g (as fed) dried distillers grains containing Bullseye mineral™ plus CoMax 100™ added to provide 7.1 mg/d of Cobalt.
[b] Control n = 14; Cobalt n = 15.

1992; Zelenák et al., 1992) and therefore increased ruminal kp (rate of passage; Owens and Goetsch, 1986) and subsequently increased passage rate of digesta out of the rumen.

Supplemental Co can improve blood concentration of glucose via succinate production (Underwood and Sutter, 2001) especially in Co-adequate diets (Tiffany et al., 2002). Supplemental glucose or propionate has been shown to improve N balance in lambs (Eskeland et al., 1974); therefore it was surprising that supplemental Co in the current study had little effect on N metabolism. This was in spite of a numerical increase in total tract N digested. Similarly, supplementing sheep fed Mulga leaves (Acacia aneura) with added Co had no effect on N digestibility but did lower N balance compared to unsupplemented controls (McMeniman et al., 1981).

Conclusions

Dietary Co increased forage intake in lambs although the mechanism of action is not clear. The increase in intake may have been due to improvements in ruminal fermentation related to alterations in the ruminal microbial population, specifically the cellulolytic bacteria, which appear to be most sensitive to additional Co. Further, due to the nature of this experiment, accurate evaluation of BW gain was not possible. Hence, it is unclear at this time whether or not the intake differences translate to an improvement in BW gain. Therefore, a site and extent of digestion and growth performance trial is warranted to more completely evaluate the impact of supranutritional levels of Co in growing lambs.

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