# THIAMIN AND $MgKSO_4$ SUPPLEMENTATION FOR STEERS FED CONCENTRATE DIETS[1]

A.L. Goetsch[2] and F.N. Owens[3]

## Story in Brief

Ruminal escape of thiamin with and without supplemental $MgKSO_4$ (1.8 percent of diet dry matter) was measured with mature steers. Thiamin escape averaged 53 percent, but thiamin flow to the small intestine was reduced by 29 percent by addition of $MgKSO_4$ to the diet. Thiamin supplementation alone markedly decreased ruminal disappearance of fed organic matter and nitrogen and total tract disappearance of starch and nitrogen, and increased rumen microbial efficiency, but $MgKSO_4$ addition to the high thiamin diet reversed these effects of thiamin. Thiamin supplementation of the diet without added $MgKSO_4$ tended to elevate plasma thiamin, whereas $MgKSO_4$ addition to the diet with supplemental thiamin tended to lower plasma thiamin. Results indicate that thiamin deficiency in ruminants can be alleviated by supplemental thiamin in the diet but deficiency can be induced by high dietary $MgKSO_4$.

(Key Words: $MgKSO_4$, Sulfate, Thiamin, Site of Digestion, Cattle.)

## Introduction

Polioencephalomalacia (PEM) is a persistent problem with feedlot cattle. Ruminal escape of dietary thiamin is suggested to be about 52 percent whereas ruminal synthesis is about 8 mg per kg digestible or organic matter consumed (Zinn et al., 1986). Both may decrease with acidic ruminal conditions of cattle fed high grain diets (Miller et al., 1983). Thiamin-HCl often is fed to feedlot cattle if PEM is diagnosed. Problems with PEM have been more prevalent among cattle fed high levels of gypsum (calcium sulfate) or $MgKSO_4$ suggesting that sulfate can precipitate the problem (Sadler et al., 1983). In the rumen, sulfate is reduced to sulfite and sulfide. Sulfite ions can cleave thiamin at the methylene bridge and dislodge the thiazole ring (Brent and Bartley, 1984). This study was conducted to evaluate the ruminal escape of supplemental thiamin and effects of dietary sulfate on thiamin flow to the duodenum of steers fed a finishing diet.

## Materials and Methods

Four mature dairy steers (1023 lb) cannulated in the rumen and duodenum were each fed 4 different diets (with or without 1.8 percent supplemental $MgKSO_4$ and with or without addition of 1 g thiamin-HCl per animal per day; Table 1). Diets were formulated to have a

[1]The authors gratefully acknowledge assistance of R. L. Stewart, Roche Chemical Division, Hoffman-La Roche, Inc., Nutley, New Jersey 07110 for partial financial support and thiamin analyses.
[2]Former Research Associate [3]Professor

Table 1. Diet composition.

| Ingredient | Diet | |
|---|---|---|
| | Basal | Sulfate |
| Sorghum grain, ground | 33.25 | 31.45 |
| Corn, ground | 35.00 | 34.40 |
| Cottonseed hulls | 15.00 | 15.00 |
| Dehydrated alfalfa | 5.00 | 5.00 |
| Alfalfa hay, ground | 3.00 | 3.00 |
| Soybean meal | 1.00 | 1.60 |
| Molasses | 4.00 | 4.00 |
| Urea | 1.00 | 1.00 |
| Limestone | 1.61 | 1.61 |
| Dicalcium phosphate | .34 | .34 |
| Trace mineralized salt | .50 | .50 |
| Chromic oxide | .30 | .30 |
| $MgKSO_4$ | 0 | 1.80 |
| Thiamin | - + | - + |

composition similar to that implicated to cause PEM (Sadler et al., 1983). Calculated sulfur contents of the diets without and with added $MgKSO_4$ were .15 and .51 percent (dry matter basis), respectively. The level of $MgKSO_4$ added was about double the 0.8 to 1 percent rate normally fed in finishing cattle diets. Thus, treatments consisted of the basal diet (B), the sulfate diet with no supplemental thiamin added (S), B with supplemental thiamin (T) and S with supplemental thiamin (TS). Chromic oxide was included in the diets as an indigestible marker. Steers were fed on days 1 through 8 at 0900 and 1700 h and at 0900 and 2100 h on d 9 through 15 with daily dry matter intake limited to 1.36 percent of body weight.

Feed, ruminal, duodenal, fecal and plasma samples were collected on days 13 through 15. Samples were analyzed for all or part of the following: DM, ash, nitrogen (N), starch, chromium, nucleic acid-N, ammonia-N and thiamin.

## Results and Discussion

The thiamin content of the basal diet ranged from 2.9 to 4.5 ppm compared with a calculated thiamin content of 3.3 ppm. Thiamin supplementation increased its concentration to 5220 ppm.

Thiamin intakes (Table 2) averaged 26 and 951 mg daily without and with added thiamin, respectively. Thiamin feeding increased duodenal flow of thiamin. Ruminal thiamin balance should represent the net difference between synthesis and destruction in the rumen because thiamin is not absorbed from the rumen. Calculated by difference, apparent ruminal escape of dietary thiamin was 60.5 percent without and 45.8 percent with added sulfate. These are quite similar to the escape value (52 percent) reported by Zinn et al. (1986). Added sulfate reduced duodenal thiamin passage from the thiamin diet, possibly due to increased thiamin destruction within the rumen.

Table 2. Thiamin passage.

| Item | Diet[a] | | | | Sulfate[b] | | Thiamin[c] | |
|---|---|---|---|---|---|---|---|---|
| | B | S | T | TS | 0 | + | 0 | + |
| Intake, mg | 23.6[d] | 28.4[d] | 942.8[e] | 959.9[e] | 483.2 | 494.1 | 26.0[d] | 951.3[e] |
| Entering intestine, mg | 57.1[d] | 38.3[d] | 612.8[e] | 465.1[e] | 335.0 | 251.7 | 47.7[d] | 539.0[e] |
| Net appearance in rumen, mg/d | 33.6[d] | 10.0[d] | -330.0[e] | -494.8[e] | -148.2 | -242.4 | 21.8[d] | -412.4[e] |
| Apparent escape, % of intake | | | 60.5 | 45.8 | | | | |
| Apparent synthesis, mg/kg OM digested in total tract | 7.6 | 3.6 | | | | | | |
| Blood plasma concentration, mg/dl | 4.5 | 8.3 | 10.3 | 3.8 | | | | |

[a]Diet: B = basal; S = sulfate (1.8% $MgKSO_4$ added); T = thiamin (1 g thiamin-HCl added daily); TS = sulfate plus thiamin (1.8% $MgKSO_4$ and 1 g thiamin-HCl added daily).
[b]Sulfate: 0 = no added sulfate; + = sulfate added as 1.8% $MgKSO_4$.
[c]Thiamin: 0 = no added thiamin; + = 1 g thiamin-HCl added daily.
[de]Means in a row with diet, sulfate or thiamin groupings with different superscripts differ ($P<.05$).

With the basal diet, duodenal thiamin flow was 241 percent of intake, but sulfate supplementation of the basal diet reduced duodenal thiamin flow to 135 percent of thiamin intake. These results contrast those of Miller et al. (1983) who reported a net loss of thiamin in the rumen of animals fed high grain diets composed of corn, oats, barley and wheat. With their sorghum grain diet, however, duodenal thiamin passage exceeded intake by 8 mg or 79 percent. In studies by Zinn et al. (1986) with corn-based diets, ruminal outflow consistently exceeded thiamin intake. We used a diet with a lower level of concentrate than used by Miller et al. (1983) which contained both corn and sorghum. In our experiment, synthesis of thiamin, calculated after subtracting for escape of dietary thiamin as cited above, was 7.6 and 3.6 mg per kg digestible organic matter (OM) consumed for diets without and with supplemental sulfate. For the control diet, this value is quite similar to the 8.3 value proposed by Zinn et al. (1986) who fed lower levels of thiamin (20 or 200 mg daily), but thiamin synthesis appeared to be reduced by added sulfate.

Blood plasma thiamin levels (Table 2) were similar for all diets; however, an interaction between sulfate and thiamin supplementation was detected. Sulfate tended to increase plasma thiamin with the basal diet, whereas sulfate tended to depress plasma thiamin with the thiamin diet. This could be due to altered thiamin absorption. Absorption of thiamin is thought to be a carrier-mediated mechanism, with absorption decreasing as the carrier becomes saturated. The drop in plasma thiamin with sulfate supplementation also could reflect effects of sulfate on tissue use or excretion of thiamin.

Thiamin supplementation tended to increase ruminal pH (Table 3). This may be due to depressed ruminal digestion of organic matter with thiamin supplementation or to stimulation of activity of lactate-utilizing ruminal bacteria. A very low pH can cause an acid-shock of ruminal bacteria which results in release of the bacterial cell surface-bound thiaminase I enzyme (Brent and Bartley, 1984). With the high ruminal pH maintained in this study, level of active thiaminase I enzyme in rumen should have been low. The high and stable pH probably reflects the restricted intake of feed and presence of 23 percent

**Table 3. Measures of digesta pH.**

| | Diet[a] | | | | Sulfate[b] | | Thiamin[c] | |
|---|---|---|---|---|---|---|---|---|
| Item | B | S | T | TS | 0 | + | 0 | + |
| Ruminal pH | 6.48 | 6.46 | 6.60 | 6.49 | 6.54 | 6.48 | 6.47 | 6.55 |
| Duodenal pH | 2.43 | 2.74 | 2.17 | 2.57 | 2.30 | 2.66 | 2.59 | 2.37 |
| Fecal pH | 5.98[d] | 6.31[e] | 5.86[d] | 6.37[e] | 5.92[d] | 6.34[e] | 6.15 | 6.12 |

[a]Diet: B = basal; S = sulfate (1.8% $MgKSO_4$ added); T = thiamin (1 g thiamin-HCl added daily; TS = sulfate plus thiamin (1.8% $MgKSO_4$ and 1 g thiamin-HCl added daily.
[b]Sulfate: 0 = no added sulfate; + = sulfate added as 1.8% $MgKSO_4$.
[c]Thiamin: 0 = no added thiamin; + = 1 g thiamin-HCl added daily.
[de]Means in a row with diet, sulfate or thiamin groupings with different superscripts differ ($P<.05$).

Table 4. Digestion measures.

| Item | Diet[a] | | | | Sulfate[b] | | Thiamin[c] | |
|---|---|---|---|---|---|---|---|---|
| | B | S | T | TS | 0 | + | 0 | + |
| Organic matter digestion | | | | | | | | |
| Apparent ruminal, % of intake | 35.9[d] | 34.9[d] | 19.9[e] | 40.5[d] | | | | |
| True ruminal, % of intake | 45.5[d] | 44.1[d] | 30.1[e] | 49.4[d] | | | | |
| Postruminal, % of intake | 17.6 | 20.8 | 31.1 | 22.1 | 24.3 | 21 5 | 19.2 | 26.6 |
| Postruminal, % of available | 42.5 | 45.0 | 52.4 | 52.2 | 47.5 | 48.6 | 43.8 | 52.3 |
| Total, % of intake | 63.0 | 64.9 | 61.3 | 71.5 | 62.2 | 68.2 | 64.0 | 66.4 |
| Starch digestion | | | | | | | | |
| Ruminal, % of intake | 69.7 | 71.4 | 53.5 | 78.1 | | | | |
| Postruminal, % of intake | 20.4 | 22.4 | 29.3 | 17.7 | 24.9 | 20.1 | 21.4 | 23.5 |
| Postruminal, % of available | 65.6 | 77.9 | 54.4 | 76.8 | 60.0 | 77.3 | 71.7 | 65.6 |
| Total, % of intake | 90.2[d] | 93.8[d] | 82.9[e] | 95.8[d] | | | | |
| Nitrogen disappearance | | | | | | | | |
| Ruminal, % of intake | 28.0[d] | 24.8[de] | 9.9[e] | 34.2[d] | | | | |
| Postruminal, % of intake | 28.5 | 30.4 | 35.5 | 30.6 | 32.0 | 30.5 | 29.4 | 33.1 |
| Postruminal, % of available | 62.4 | 61.2 | 60.8 | 65.8 | 61.8 | 63.3 | 61.6 | 63.5 |
| Total, % of intake | 56.6[d] | 55.1[de] | 45.4[e] | 64.8[d] | | | | |
| Microbial efficiency, g microbial N/kg OM fermented | 22.7[d] | 20.9[d] | 36.3[e] | 18.0[d] | | | | |

[a]Diet: B = basal; S = sulfate (1.8% $MgKSO_4$ added); T = thiamin (1 g thiamin-HCl added daily); TS = sulfate plus thiamin (1.8% $MgKSO_4$ and 1 g thiamin-HCl added daily).
[b]Sulfate: 0 = no added sulfate; + = sulfate added as 1.8% $MgKSO_4$.
[c]Thiamin: 0 = no added thiamin; + = 1 g thiamin-HCl added daily.
[de]Means in a row with diet, sulfate or thiamin groupings with different superscripts differ (P<.05).

dietary roughage. Duodenal pH was not affected by diet, but pH of feces increased with $MgKSO_4$ supplementation.

The amount of OM digested in the rumen decreased with thiamin addition alone (Table 4) but postruminal and total tract OM digestion was similar for all diets. Interactions between supplementation of thiamin and sulfate also were detected for starch entering the duodenum and exiting the rectum, and for digestion of starch in the rumen and total tract. Total tract starch digestion was lowest for the thiamin diet. Ruminal and total tract disappearance of fed N was lower with the thiamin diet than with the basal and sulfate plus thiamin diets (Table 4) whereas microbial efficiency (Table 4) was greatest for the thiamin diet.

These shifts in ruminal conditions were not anticipated. Thiamin supplementation at a lower level, 20 percent of our supplemental level, with concurrent addition of other B-vitamins to a 44 percent roughage diet for receiving cattle did not alter ruminal digestion in a study by Zinn et al., (1986). Results might differ due either to simultaneous addition of other B-vitamins or to specific effects of a very high level of thiamin supplementation on ruminal digestion or rate of digesta outflow from the rumen. The thiamin effect seems too large to be explained by an increase in the rate of digesta passage from the rumen alone, so altered microbial activity is suspected. All levels should have exceeded microbial requirements for thiamin.

In summary, ruminal escape of dietary thiamin was about 50 percent. Hence, dietary supplementation should be useful to treat PEM. Addition of $MgKSO_4$ to the diet reduced duodenal flow of thiamin due both to reduced escape and reduced ruminal synthesis of thiamin. This depression may explain why PEM is encountered in cattle fed high concentrate diets containing an excessive level of sulfate. $MgKSO_4$ supplementation tended to increase plasma thiamin concentrations with a low thiamin diet but decreased plasma thiamin with a thiamin supplemented diet. It is unknown if or how supplementation of magnesium and potassium along with dietary sulfate might have altered these responses. The depression of ruminal digestion caused by supplementation of the diet with 1 g thiamin-HCl daily was circumvented by dietary sulfate inclusion, but mechanisms responsible for these alterations are unknown at present. Long term effects of occasional thiamin supplementation are unknown. If metabolism, excretion or ruminal degradation were increased, infrequent feeding could theoretically induce PEM. But in this study, ruminal degradation of thiamin did not appear to increase with thiamin feeding.

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