

## THE EFFECT OF SUPRA-NUTRITIONAL LEVEL OF Cu ON VITAL SIGNS GROWTH PERFORMANCE, AND Cu STATUS IN GOAT KIDS

S. G. Solaiman\*<sup>1</sup>, C. E. Shoemaker\*<sup>2</sup>, and G. H. D'Andrea<sup>†</sup>

\* Department of Agriculture Sciences, Tuskegee University, Tuskegee, AL 36088 and

<sup>†</sup>Alabama Veterinary Diagnostic Laboratory, Auburn, AL 36830

<sup>1</sup>Correspondence: 105 Milbank Hall, phone: 334-727-8401; fax: 334-727-8552

Email: [ssolaim@tuskegee.edu](mailto:ssolaim@tuskegee.edu).

Presented at the 2005 Nutrition Conference sponsored by Department of Animal Science, UT Extension and University Professional and Personal Development The University of Tennessee.

### Introduction

Appropriate trace mineral supplementation is essential for maintaining optimum level of growth and performance of the animal. Assessment of trace element status identifies whether current mineral supplementation of livestock feed is adequate and whether improved productivity is likely to occur with changes in supplementation. Copper is an essential trace element that plays an important role in the biochemical reactions of the body; however, its requirement, and interaction with other minerals is not clearly understood. Solaiman et al. (2001) demonstrated the positive effect of feeding Cu, at 10 times the NRC (1981) recommended level for goats; however, results from cattle studies are not consistent. In a study with growing Angus steers, supplementation of 5 mg of Cu/kg DM to a corn silage diet containing 5.2 mg of Cu/kg DM increased intake but did not affect gain or gain:feed (Ward and Spears, 1997). In contrast, Gengelbach (1994) found reduced intake and increased gain:feed in Angus steers when 10 mg of Cu/kg DM was supplemented to a corn silage diet containing 5.3 mg of Cu/kg DM. A number of factors, such as breed (Mullins et al., 2003), diet (Arthington and Pate, 2002), and the concentration of Cu antagonists (Fe, S, and Mo) may affect responses of cattle to supplemental Cu. Reports on weanling pigs indicates that supra-nutritional addition of 250 ppm Cu stimulated growth beyond the nutrient requirements (Hill et al., 2000).

Production efficiency should be improved by producing superior animals in terms of meat quality. In order to produce a high quality meat product from goats more information is needed on their mineral requirements in relation to nutrition, toxicology, and physiological status of the animal. This experiment was conducted to determine the possible strategic role of Cu at supra-nutritional level on health, growth performance, and Cu status of growing goat kids.

### Materials and Methods

#### Animals

Fifteen Boer x Spanish goat kids (BW of  $21.3 \pm 0.7$  kg) 4 to 5 mo of age were used for this experiment. The Tuskegee University Animal Care and Use Committee approved animal care, handling and sampling procedures. Animals were treated for internal parasites using Cydectin (Moxidectin; Fort Dodge Animal Health, Fort Dodge, Iowa) by oral drench prior to the start of the study and two wk into the experiment. Animals were vaccinated s.c with Clostridium

Perfringens type C & D-Tetani Bacterin-Toxoid (Bayer: Bayer Corp., Animal Health, Shawnee Mission, Kansas) and dusted along the loin area and neck for external parasites using Co-Ral 1% dust (Dale Alley Co., St. Joseph, Missouri) prior to the start of the study and two wk into the experiment. Goats were castrated followed by a s.c. injection of Liquamycin LA-200 (Pfizer: Animal Health, Exton, Pennsylvania) to prevent the occurrence of infection as recommended by a veterinarian. Animals were quarantined for a period of 30 d, during which the diet was gradually adjusted to a 70:30 grain:hay

### **Experimental Design and Treatments**

Animals were stratified by BW and randomly assigned to three experimental treatments following the quarantine period. Animals were housed individually in 1.8- x 2.1-m pen and allowed two wk of adjustment for supplemental Cu intake followed by 10 wk for performance measurement. Animals were harvested 14 wk after initiation of supplemental Cu intake. All animals received a 70% commercial grain mix (GMX, Nutrena Feed Division, Minneapolis, Minnesota) and 30% bahiagrass hay (BGH) diet. Bahiagrass hay was chopped to approximately 4 to 5 cm in length for the ease of handling and stored in plastic containers. Animals also received either 0 mg Cu, 100 mg Cu, or 200 mg Cu daily as Cu sulfate ( $\text{CuSO}_4 \cdot 5\text{H}_2\text{O}$ ) placed in porcine gelatin capsules (Torpac #13: Torpac Inc., Fairfield, New Jersey) and inserted into the esophagus with a balling gun prior to AM feeding. Levels of Cu supplements were determined according to Solaiman et al. (2001).

Feed was offered *ad libitum* to meet the requirements of animals for maintenance and 150 g of gain per day according to NRC (1981) plus 10% refusals. Grain and BGH were fed separately each day and fresh feeds were provided twice a day at 0900 h and 1700 h. Feed offered and refusals were recorded daily prior to the morning feeding and feed intake was adjusted weekly. *Ad libitum* access to water was maintained throughout the study.

### **Sample Collection**

Samples of each feed (grain and BGH) were collected daily and composites were made each month. Fecal samples were collected every two wk following BW measurement. General health parameters and BW were obtained every two wk for two consecutive days. Body weight was recorded after 4 h of feed and water restriction. Individual goat ADG was calculated as the difference between initial and final BW over the 10 wk performance phase. Vital body signs recorded were respiration rate (RR), heart rate (HR) and rectal temperature (RT). Blood samples were collected every two wk by jugular venipuncture. Heparinized, and nonheparinized trace mineral free (for Cu) vacutainer tubes (Becton Dickinson, Vacutainer System, Franklin Lakes, New Jersey) were used to collect blood. At the end of 14 wk, animals were transported to Auburn University Lambert Meat Abattoir and harvested according to USDA approved methods, after an overnight period of feed withdrawal. Liver (left lobe), bile and kidney samples were obtained from each animal postmortem. A longissimus muscle (LM) sample, 1.5 cm in depth (approximate weight of 50 to 100 g) was sliced from the right side of the carcass. Samples were placed in sealed whirlpack bags and immediately chilled on ice. Upon arrival at the laboratory, samples were frozen at  $-20^\circ\text{C}$  until further analysis.

### **Handling and Processing of Samples**

Feed samples and partially dried fecal samples were ground in a Wiley mill (Thomas Scientific; model 4) to pass through a 1 mm mesh screen, and used to determine DM and Kjeldahl-N according to AOAC (1998). Crude protein was calculated as the percentage of Kjeldahl-N x 6.25. Neutral detergent fiber, ADF and ADL were determined on grain and BGH samples according to Van Soest et al. (1991) and modified (Komarek et al., 1994) for use in an Ankom fiber apparatus (Ankom Technology Corp., Fairport, NY). Grain and BGH were analyzed for Cu, Zn and Fe concentrations using dry ashing methods as described by Hue and Evans (1986), Jackson (1970) and Walsh and Beaton (1973), respectively. Concentration of Mo in the feed was determined by ashing in a muffle furnace and digested using a microwave digestion system (MDS 2100) procedure described by Gengelbach et al. (1994). Samples were prepared using Environmental Protection Agency (EPA) protocol method 7481 referenced by Methods for Chemical Analysis of Water and Wastes (1982) and analyzed by flameless (graphite furnace) atomic absorption spectrophotometry (Perkin Elmer model 5100; equipped a Zeeman 5100).

Fecal samples were prepared by ashing one g of each composite sample in a muffle furnace at 550°C for 24 hours. The ashed samples were digested in 10 mL of 3M hydrochloric acid and 3 M nitric acid mixture solution. The samples were covered with a watch-glass and allowed to stand at room temperature for 12 h. The samples were then filtered through a # 541 Whatman filter paper into a 50 mL volumetric flask. Two mL of potassium chloride were added to each sample brought to volume with double D H<sub>2</sub>O. Copper concentrations were determined by atomic absorption spectrophotometry (Instrumentation Laboratory; model IL251) using a nitrous oxide acetylene flame at a wavelength of 324.7 nm.

Serum samples were diluted 1:4 in D H<sub>2</sub>O and Cu concentration was determined (Weinstock and Uhlemann, 1981) by flame atomic absorption spectrophotometry (Instrumentation Lab, model IL251).

Liver specific enzyme SDH activity was determined in plasma within two h of blood collection according to the procedures outlined in respective commercial kits (Kit # 50-UV, Sigma Chemical Co., St. Louis, MO) using a spectrophotometer (Thermo Spectronic Genesys 10; Fisher Scientific). An ovine SDH (SDH control S81355; Sigma Chemical) in a bovine serum base was used as a quality control measure.

Liver, kidney and LM were diced into small pieces, mixed thoroughly, and randomly sampled. Sub-samples were dried at 100°C for 48 h, weighed and 5 g DM of each sample was ashed in a muffle furnace (SyBron Thermolyne Furnatrol I; model 18200) at 600°C overnight. Ashed tissue samples (liver, kidney, bile and LM) were digested in 10 mL of HNO<sub>3</sub> over a hot plate until ash was dissolved and transferred to a plastic centrifuge tube (AOAC, 1998). Bile and LM samples were diluted to 25 mL, kidney samples were diluted to 50 mL and liver samples ranged from 50 to 150 mL dilutions with distilled water. Flame atomic absorption spectrophotometer (GBC 908AA; Perkin Elmer) determined Cu concentrations. Liver and kidney results were reported on a DM basis, while bile and LM were reported on wet basis.

## **Statistical Analysis**

Data were analyzed by the GLM procedure of SAS (SAS Inst. Inc, Cary, NC). Week and Cu level interaction were not significant. Therefore, general health parameters, BW and performance data, serum Cu and fecal Cu were averaged over the 14 wk period and analyzed as a completely randomized design with Cu levels as a source of variation. The Cu level effects were tested by a polynomial regression using orthogonal contrast for equally spaced treatments (Steel et al., 1997) established by the GLM procedure of SAS (SAS Inst. Inc.) The least square means procedure was used to compare differences between treatment means. Differences were declared significant at  $P < 0.05$ , unless otherwise indicated.

## **Results and Discussion**

### **Diet Composition**

The chemical composition of the diet used in this study is listed in Table 1. The commercial grain mix results were similar to those listed on the nutrients label. The Cu content was within the range of 10 to 20 ppm while the Zn content was higher (64.3 ppm) than the minimum of 50.0 ppm set by the manufacturer (Nutrena Feed Division, Minneapolis, Minnesota). The Mo content was determined by graphite furnace technique ( $<0.01$  ppm), which meets the recommended ratio of 4:1 Cu to Mo reported by Miller et al. (1988). Mineral content of water (obtained from the Tuskegee University Water Quality Control Laboratory, Tuskegee, AL) did not contribute to the diet.

Goats were fed a 70:30 grain: forage diet and received 14.5 mg Cu/kg of diet DM, which exceeded the 8 to 10 ppm range recommended by NRC (1981) and suggested by Kessler (1991) or the AFRC (1997). The Cu supplemented groups received 100 and 200 mg additional Cu daily, for 14 wk with no signs of toxicity such as accelerated breathing, elevated temperature, dullness, anorexia, dehydration or acute thirst observed, similar to those reported by Miller et al. (1988) and Solaiman et al. (2001).

### **Effect of Supra-nutritional level of Cu on Animal Health**

Vital signs were obtained throughout the study and are shown in Table 2. Respiration rate (RR), heart rate (HR) and rectal temperature (RT) were not affected ( $P > 0.10$ ) by feeding supplemental Cu. These means fell within the normal range of 15.0 to 76.5 breaths/ min for RR, 39.0 to 40.0°C for RT and 77.0 to 89.0 beats/ min for HR as reported by Dunn (1990) and Brooks et al. (1984). Solaiman et al. (2001) also reported no effect on vital signs with supra-nutritional levels of  $< 600$  mg Cu/d fed to Nubian goats.

Sorbitol dehydrogenase (SDH) has been shown to be an early indicator of Cu toxicity in goats (Solaiman et al., 2001). In order to assure that the supplemental Cu was below the toxic level for goats, plasma SDH enzyme was measured at the end of the 14 wk study. Mean plasma SDH values for all goats ranged from 18.0 to 24.0 U/L and were within the normal range (9.30 to 23.6 U/L) reported for goats (Boyd, 1984; Brooks et al., 1984; Solaiman et al., 2001).

### **Effect of Supra-nutritional level of Cu on Growth Performance**

Mean BW, ADG, ADFI, gain efficiency (gain:feed ratio), and percent grain consumed (PDMG) by goats fed supra-nutritional levels of Cu throughout the performance phase (70 d) are presented in Table 3. Average daily gain improved (Q,  $P = 0.01$ ) and ADFI decreased linearly (L,  $P = 0.05$ ) as Cu supplementation increased. The control group consumed a higher

grain:hay ratio (80.0 grain:20.0 hay) in the diet ( $L, P = 0.03$ ) compare to the other groups. Gain efficiency improved ( $Q, P = 0.02$ ) in the 100 mg Cu group similar to that reported (Solaiman et al., 2001) for Nubian doe goats fed 100 to 150 mg additional Cu. Results from cattle studies are not consistent. In a study with growing Angus steers, supplementation of 5 mg of Cu/kg DM to a corn silage diet containing 5.2 mg of Cu/kg DM increased intake but did not affect gain or gain:feed (Ward and Spears, 1997). In contrast, Gengelbach (1994) found reduced intake and increased gain:feed in Angus steers when 10 mg of Cu/kg DM was supplemented to a corn silage diet containing 5.3 mg of Cu/kg DM. A number of factors, such as initial Cu status, Cu content of basal diet, and the concentration of Cu antagonists (Fe, S, and Mo) may affect responses of cattle to supplemental Cu. In a study reported by Arthington et al. (2003) Braford heifers grazing bahiagrass pasture and provided molasses-cotton seed meal slurry, were supplemented with 100 mg Cu/d from either an organic or inorganic source of Cu. Heifers ADG tended ( $P = 0.11$ ) to increase, however, when Brahman crossbred steers fed stargrass hay provided with the same molasses-cotton seed meal with 10 or 30 ppm Cu diets supplemented through either an organic, inorganic or combination of the two sources did not improve ADG and gain efficiency. Breed, gender, or just diet forage base differences may have contributed to the outcome of the results. Differences in breed (Mullins et al. 2003) and diet (Arthington and Pate, 2002) responses to Cu supplementation have been documented. Supplemental Cu fed at 250 ppm also improved ADG, feed efficiency and gain:feed ratio in weanling pigs (Hill et al., 2000).

#### **Effect of Supra-nutritional level of Cu on Tissue Cu**

Concentration of Cu in different tissues (TC) of experimental goats is listed in Table 4. Liver Cu concentration increased linearly ( $L, P = 0.0001$ ) as Cu supplementation increased. The control group and 100 mg Cu group had liver Cu concentrations of 206 and  $504 \pm 59.0$  mg/kg DM, respectively. These values are within the normal range of 157 to 590 ppm Cu, reported by Beck (1956) and Solaiman et al. (2001) for goats. Dietary components and Cu level directly affects liver Cu accumulation (Arthington and Pate, 2002). Liver Cu was greater for Brahman steers fed 30 ppm Cu vs. 10 ppm regardless of source, organic or inorganic (Arthington et al., 2003). The concentration of Cu in serum fluctuates with age, stress, infection and feed restrictions of the animal (Kincaid, 1999). Serum Cu was maintained within the normal range for all goats receiving supplemental Cu when compared to the control group ( $P > 0.10$ ). Solaiman et al. (2001) also reported no difference in plasma Cu concentration for Nubian doe goats fed supra-nutritional level (50 to 600 ppm) of Cu over a 31 wk experimental period. Engle and Spears (2000) reported higher ( $P < .05$ ) plasma and liver Cu concentrations in Angus or Angus x Hereford steers receiving 40 mg Cu/kg DM from  $\text{CuSO}_4$  than those supplemented with 20 mg Cu/kg DM at the end of both the growing and finishing phases. However, plasma Cu was within the normal range reported for all animals (0.5 to 1.5 mg/L) by Davis and Mertz (1987).

Ingested Cu is excreted through the feces with only a small amount (10 to 50  $\mu\text{g}$ ) excreted through the kidneys via urine. In all species high proportion of ingested Cu appears in feces (Davis and Mertz, 1984), and the biliary system is recognized as the principal excretory pathway of absorbed Cu. The kidney and bile Cu concentrations, among treatment groups, were similar ( $P > 0.10$ ) in the present study. Dietary Cu directly affects fecal Cu excretion (Groff and Gropper, 1999). Feces are the main excretory routes for Cu as it was observed in present study, the level of Cu in feces linearly increased ( $L, P = 0.0001$ ) as Cu supplementation increased. The LM Cu concentration tended to increase linearly ( $L, P = 0.07$ ) with increased Cu in the diet and

it was numerically higher for the 200 mg Cu supplemented group ( $5.74 \pm 1.04$  mg/kg) compared to control and 100 mg Cu group. Results for 0 and 100 mg Cu group were similar to those (1 to 3 ppm) reported by Solaiman et al. (2001) for muscle tissues of Nubian doe goats fed the control diet.

### **Impact**

These data indicate that supra-nutritional level of Cu fed to Boer x Spanish goat kids at 100 mg/d enhanced ADG, reduce ADFI and improved gain efficiency without adversely affecting the health and well being of the animals. Performance data suggest that Cu levels above NRC guidelines improved animal efficiency, therefore Cu requirements in goats must be re-evaluated and refined to account for animal, as well as, environmental impact.

## Literature Cited

AOAC. 1998. Official Methods of Analysis. 16<sup>th</sup> ed. Association of Official Analytical Chemists, Gaithersburg, MD.

Arthington, J.D., and F. M. Pate. 2002. Effect of corn- vs molasses-based supplements on trace mineral status in beef heifers J. Anim. Sci. 80:2787–2791.

Arthington, J.D., F. M. Pate, and J. W. Spears. 2003. Effect of copper source and level on performance and copper status of cattle consuming molasses-based supplements. J. Anim. Sci. 81:1357-1362.

Beck, A.B. 1956. The copper content of the liver and blood of some vertebrates. Aust. J. Zool. 4:1-18.

Boyd, J.W. 1984. The interpretation of serum biochemistry test results in domestic animals. Vet. Clin. Pathol. 13:7-14.

Brooks, D.L., P.C. Tillman, and S.M. Niemi. 1984. Ungulates as laboratory animals. In: Fox, Cohen, Loew (Eds.), Laboratory Animal Medicine. pp 273-295. Academic Press, NY.

Davis, G. K., Mertz, W., 1987. Copper. In: Trace Elements in Human and Animal Nutrition, 5th. Edition. Mertz, W., Ed. Academic Press, NY, pp. 301-350.

Dunn, P. 1990. The Goatkeeper's Veterinary Book. 2th ed. Farming Press Ltd. Ipswich, UK.

Gengelbach, G. P. 1994. Effects of copper deficiency on cellular immunity in cattle. Ph.D. dissertation. North Carolina State University, Raleigh.

Gengelbach, G.P., J.D. Ward, and J.W. Spears. 1994. Effect of dietary copper, iron, and molybdenum on growth and copper status of beef cows and calves. J. Anim. Sci. 72:2722-2727.

Groff, J.L., and S.S. Gropper. 1999. Advanced Nutrition and Human Metabolism. Wadsworth-Thomson Learning, Belmont, CA.

Hill, G.M., G.L. Cromwell, T.D. Crenshaw, C.R. Dove, R.C. Ewan, D.A. Knabe, A.J. Lewis, G.W. Libal, D.C. Mahan, G.C. Shurson, L.L. Southern, and T.L. Veum. 2000. Growth promotion effects and plasma changes from feeding high dietary concentrations of zinc and copper to weanling pigs (regional study). J. Anim. Sci. 78:1010-1016.

Hue, N.V., and C.E. Evans. 1986. Procedures used for soil and plant analysis by the Auburn University Soil Testing Laboratory. Alabama Agric. Exp. Sta., Dep. of Agron. And Soils, Dep. Series 106.

Jackson, M.L. 1970. Soil chemical analysis. Prentice-Hall, Inc., Dep. of Soil Sci., Univ. of Wisconsin, Madison, WI.

- Kessler, J. 1991. Mineral nutrition of goats. In: Morand-Fehr, P. (Ed.) Goat Nutrition. Academic Press, NY, pp 10
- Kincaid, R.L. 1999. Assessment of trace mineral status of ruminants: A review. Proc. American Society of Anim. Sci.
- Komarek, A.R. 1993. An improved filtering technique for the analysis of neutral detergent fiber and acid detergent fiber utilizing the filter bag technique. J. Anim. Sci. 71:824-829.
- Methods for Chemical Analysis of Water and Waste. 1982. EPA-600/4-82-055, December , Method 246.2.
- Miller, J.K., N. Ramsey, and F.C. Madsen. 1988. The trace elements. In: D.C. Church (ed.) The Ruminant Animal; Digestive Physiology and Nutrition. pp 343-400. Prentice-Hall, Inc., NJ.
- Mullis, L. A., J. W. Spears, and R. L. McCraw. 2003. Effects of breed (Angus vs. Simmental) and copper and zinc source on mineral status of steers fed high dietary iron. J. Anim. Sci. 81:318-322.
- NRC. 1981. Nutrient requirements of domestic animals. No. 15. Nutrient requirements of goats: Angora, dairy and meat goats in temperate and tropical countries. National Research Council, National Academy of Science, Washington, DC.
- SAS. 1998. SAS User's Guide: Statistics (Version 8). SAS Institute Inc., Cary, NC.
- Solaiman, S.G., M.A. Maloney, M.A. Qureshi, G. Davis and G.D'Andrea. 2001. Effects of high copper supplements on performance, health, plasma copper and enzymes in goats. Small Ruminant Res. 41:127-139.
- Steel, R.G., J.H. Torrie, and D.A. Dickey. 1997. Principles and Procedures of Statistics: A Biometrical Approach. 3rd ed. WCB/Mcgraw-Hill Co., NY.
- Van Soest, P.J., J.B. Robertson, and B.A. Lewis. 1991. Methods for dietary fiber, neutral detergent fiber, and non starch polysaccharides in relation to animal nutrition. J. Dairy Sci. 74:3583-3597.
- Walsh, L.M., and J.D. Beaton. 1973. Soil testing and plant analysis. SSSA, Madison, WI.
- Ward, J.D., and J.W. Spears. 1997. Long-term effects of consumption of low-copper diets with or without supplemental molybdenum on copper status, performance and carcass characteristics of cattle. J. Anim. Sci. 75:3057-3065.
- Weinstock, N. and M. Uhlemann. 1981. Automated determination of copper in undiluted serum by atomic absorption spectroscopy. Clin. Chem. 27:1438.

Table 1. Chemical composition and mineral content of grain, hay and water consumed by goat kids

Item <sup>a</sup>	Commercial Grain mix	Bahaigrass hay	Water
	----- % -----		
DM	88.0	92.0	----
CP	18.2	7.90	----
Ether Extract	2.90	----	----
NDF	16.5	72.7	----
ADF	6.90	32.7	----
Lignin	1.20	2.80	----
Ash	5.80	3.20	----
	----- ppm -----		
Cu	16.0	8.71	0.00
Fe	209	85.3	0.00
Mo	<0.01	<0.01	0.00
Zn	64.3	15.5	0.70

<sup>a</sup> Values are on DM basis except DM.

Table 2. Effects of supra-nutritional level of Cu on vital signs of goat kids

Item <sup>a</sup>	Added Cu mg/d			SEM	<i>P</i> -value <sup>b</sup>	
	0	100	200		Linear	Quadratic
RR (breaths/min)	37.3	35.6	38.9	1.71	0.51	0.24
RT (°C)	39.2	39.1	39.2	0.05	0.87	0.10
HR (beats/min)	90.0	87.8	87.0	1.58	0.18	0.72

<sup>a</sup> RR: respiration rate; HR: Heart rate; RT: rectal temperature.

<sup>b</sup> Based on orthogonal contrast for equally spaced treatments.

Table 3. Effects of supra-nutritional level of Cu on performance of goat kids

Item <sup>a</sup>	Added Cu mg/d			SEM	P-value <sup>b</sup>	
	0	100	200		Linear	Quadratic
70 day performance period						
BW, kg						
Initial	22.4	22.4	22.3	1.79	0.99	0.98
Final	31.6	32.7	30.5	1.85	0.69	0.48
ADG, g	131	147	117	6.09	0.11	0.01
ADFI, kg of DM	1.21	1.11	1.03	0.06	0.05	0.90
PDMG	80.0	78.0	78.0	0.57	0.03	0.18
Gain:Feed	0.11	0.13	0.11	0.01	0.67	0.02

<sup>a</sup> PDMG= Percent dry matter grain.

<sup>b</sup> Based on orthogonal contrast for equally spaced treatments.

Table 4. Effects of supra-nutritional levels of Cu on select tissue Cu in goat kids

Item <sup>a</sup>	Added Cu mg/d			SEM	P-value <sup>b</sup>	
	0	100	200		Linear	Quadratic
Serum Cu (mg/L)	0.82	0.78	0.86	0.03	0.35	0.14
	ppm					
Liver	206	504	778	59.0	0.0001	0.87
Kidney	15.6	17.2	17.8	0.88	0.10	0.65
Bile	0.89	1.38	1.45	0.26	0.16	0.52
Fecal	29.4	31.6	563	27.4	0.0001	0.56
LM	2.87	2.73	5.74	1.04	0.07	0.24

<sup>a</sup> Liver, kidney and fecal Cu are on DM basis, bile and longissimus muscle (LM) Cu are on wet basis.

<sup>b</sup> Based on orthogonal contrast for equally spaced treatments