Asian-Aust. J. Anim. Sci.
Vol. 22, No. 12 : 1648 - 1653
December 2009

www.ajas.info

Effects of Source of Supplemental Zinc on Performance, Nutrient Digestibility and Plasma Mineral Profile in Cashmere Goats*

Wenbin Jia, Xiaoping Zhu, Wei Zhang, Jianbo Cheng[1], Cuihua Guo and Zhihai Jia**
College of Animal Science and Technology, China Agricultural University, Beijing, 100193, China

ABSTRACT : This experiment was designed to evaluate the effects of source of supplemental zinc (Zn) on performance, nutrient digestibility and plasma mineral profile in Cashmere goats during the cashmere fiber growing period. Twenty-seven Liao Ning Cashmere wether goats (9-10 month of age; initial BW = 19.31±0.32 kg) were fed a basal diet (containing 22.3 mg Zn/kg DM) with no supplemental Zn (control) or 20 mg of supplemental Zn/kg of DM from Zn sulfate ($ZnSO_4$) or Zn methionine (ZnMet) for 60 days including a 10-day metabolism trial. Average daily gain (ADG) ($p<0.05$) and gain:feed (G/F) ($p<0.05$) were increased by Zn supplementation, but no differences were noted between Zn sources ($p>0.05$). The length and diameter of cashmere fiber did not differ among treatments ($p>0.05$). Zn supplementation had no influence on digestibility of DM, CP, EE and NDF ($p>0.05$). However, ADF digestibility in the group supplemented with ZnMet was significantly higher than in other treatments ($p<0.05$). Plasma Zn was increased ($p<0.05$) and Cu tended to be decreased ($p = 0.057$) by Zn supplementation, but no differences were found between Zn sources ($p>0.05$). Plasma alkaline phosphatase activity (AKP) was improved by Zn supplementation ($p<0.05$) and was higher in the $ZnSO_4$ than the ZnMet group ($p<0.05$). Zn retention was increased ($p<0.05$) and apparent absorption rate was decreased ($p<0.05$) by Zn supplementation. The results indicate that supplementation of 20 mg Zn/kg DM either as $ZnSO_4$ or ZnMet in the basal diet containing 22.3 mg Zn/kg DM can improve growth performance in Cashmere goats, and effectiveness of the two sources is similar on performance measurements. (**Key Words :** Cashmere Goat, Nutrient Digestibility, Performance, Plasma Mineral Profile, Zinc)

INTRODUCTION

Zinc (Zn) is an essential element required by ruminants for a number of biochemical functions. Early work suggested that Zn deficiencies can affect growth, reproduction, immune system and gene expression in ruminants (Underwood and Suttle, 1999). In recent years, use of organic Zn for supplementation of ruminant diets has increased but whether organic forms are more effective than inorganic forms remains controversial. For example, Garg et al. (2008) observed significantly improved ADG and feed efficiency in lambs given ZnMet compared to a $ZnSO_4$-supplemented group. Puchala et al. (1999) found that ADG was greater for Angora goats supplemented with ZnMet compared to a ZnO group. In contrast, Nunnery et al. (1996) reported that ADG by steers supplemented with $ZnSO_4$ was 7.4% greater than those supplemented with ZnMet, but feed intake and efficiency were similar. Galyean et al. (1995) reported no differences in ADG and feed efficiency in steers fed ZnO or ZnMet. Similar results were also observed in Angus and Hereford×Angus heifers (Spears and Kegley, 2002).

China is the largest producer of cashmere fiber, accounting for 50% of the world's total production (Bai et al., 2006). The Inner Mongolian White Cashmere and Liao Ning White Cashmere are two of the major Cashmere goat breeds in China (Zhang et al., 2007). There is no information available regarding supplementary effects of different Zn sources in Cashmere goats. Therefore, the objective of the current study was to investigate effects of dietary supplementation with ZnMet or $ZnSO_4$ on cashmere fiber growth, nutrient digestibility and plasma mineral profile in Liao Ning Cashmere goats.

MATERIALS AND METHODS

All procedures were approved by the China Agricultural

* This work was supported in part by a grant from National Key Technologies R & D Program (No. 2006BAD14B07 and 2006 BAD01A11).
** Corresponding Author: Zhihai Jia. Tel: +86-10-6273-2728, Fax: +86-10-6273-2728, E-mail: jzh331@cau.edu.cn
[1] College of Animal Science and Technology, Anhui Agricultural University, Hefei 230036, China.
Received November 25, 2008; Accepted June 25, 2009

University Institutional Animal Care and Use committee.

Animals, diets and feeding

Twenty-seven Liao Ning Cashmere wether goats (9-10 month of age, 19.31±0.32 kg mean BW) were housed in individual wooden pens (1.8 m×2.1 m) with *ad libitum* access to a diet consisting of 70% hay (Chinese wildrye) and 30% concentrate. Ingredients and chemical composition of the basal diet are shown in Table 1. The basal diet was formulated to meet nutritional requirements of goats gaining 50 g/d (NRC, 1981). Feed was offered daily at 08:30 and 17:00 h in two equal portions. Goats had *ad libitum* access to water (less than 0.01 mg Zn/L, other minerals undetectable) throughout the study except during BW measurements.

All Cashmere goats were fed the basal diet for 14 d, then stratified by BW and assigned randomly to one of three experimental treatments (n = 9 goats per treatment): i) control (no supplemental Zn), ii) 20 mg Zn/kg DM from $ZnSO_4$, and iii) 20 mg Zn/kg DM from ZnMet. Zn was added to the premix using finely ground maize as a carrier and mixed with concentrate. The experiment lasted 60 days including a 10-d metabolism trial.

Sample collection

Daily feed offerings and refusals were recorded prior to the morning feeding to obtain feed intake for each goat. BW was obtained before the goats were fed in the morning for three consecutive days at the start and end of the experiment. Blood samples were collected on day 60 via jugular venipuncture in heparinized-trace tubes prior to the morning feeding. Blood samples were centrifuged at 3,000×g for 15 min and plasma was frozen at -20°C in 5 ml polyethylene tubes until analysis.

Goats were shorn of fibers from a 10 cm^2 patch on the right scapular at the beginning of the study. On day 60 fiber samples were removed using stainless steel clippers from the 10 cm^2 patch. The samples were stored in sealed polythene bags at room temperature until analysis.

On day 35, all goats were allocated to metabolism cages to study the effects of Zn source on apparent nutrient digestibility. After a 7-d adaptation period, total faeces and urine were collected from each goat for 3 d. Faeces and urine excreted in 24 h were collected into plastic bags and weighed at 08:30 h daily. Approximately 10% of the faeces and urine were sub-sampled into plastic bags. To prevent N loss, 50 ml of 10% sulfuric acid was added to the samples. Samples were immediately labeled and frozen at -20°C until analysis.

Analytical procedures

DM content of feed and faeces samples were determined after drying at 105°C for 24 h in a forced air-drying oven (AOAC, 1990). N contents of feed, faeces and urine samples were determined by the Kjeldahl method (AOAC, 1990). Neutral detergent fiber (NDF) and acid detergent fiber (ADF) were measured according to Van Soest et al. (1991). Ether extract (EE) was determined by the Soxhlet method after extraction with petroleum ether (AOAC, 1990). Ca and P concentrations of feed samples were determined by a wet ash method (AOAC, 1990) and colorimetry (AOAC, 1990), respectively. Zn, Cu, Fe and Mn concentrations of feed and plasma. Zn concentrations of faeces, water and urine were analyzed by atomic absorption spectrophotometry (Model 5100, HGA-600 Graphite Furnace; Perkin-Elmer, USA). Plasma AKP was measured using an alkaline phosphatase kit (Nanjing Jiancheng Bioengineering Institute, China). The length of cashmere fiber was estimated using a scaled ruler (Zhang et al., 2007), and its diameter measured on a random sample of 200 fibers as described by Shahjalal et al. (1992).

Table 1. Ingredients and chemical composition of the basal diet

Item	Concentration
Ingredient (%, as fed basis)	
Hay[a]	70.0
Corn	19.0
Wheat bran	4.20
Soybean meal	5.40
Limestone	0.10
Dicalcium phosphate	0.30
Salt	0.99
Vitamin premix[b]	0.01
Chemical composition (DM basis)	
Crude protein (%)	9.74
Dry matter (%)	90.5
Neutral detergent fiber (%)	50.1
Acid detergent fiber (%)	30.9
Calcium (%)	0.45
Phosphorus (%)	0.30
Zn (mg/kg)	22.3
Cu (mg/kg)	7.93
Fe (mg/kg)	256.3
Mn (mg/kg)	15.8

[a] 92.3% DM, 8.44% CP, 0.51% Ca, 0.20% P, 1.08 mg/kg Mo, 166 mg/kg Fe, 8.53 mg/kg Cu.

[b] Provided per kilogram of diet: 54,000,000 IU of vitamin A, 10,800,000 IU of vitamin D, 18,000 IU of vitamin E.

Statistical analysis

The data were analyzed using the GLM procedure (SPSS, 1996). The following model was used: $Y_{ij} = \mu + T_i + \varepsilon_{ij}$, where Y_{ij} is the dependent variable; μ is the overall mean; T_i is the effect of Zn supplementation (i = 1, 3); ε_{ij} is the random error. Duncan's multiple range test was used to detect statistical significance between treatments.

Table 2. Effects of source of supplemental Zn on growth performance and cashmere fiber characteristics of Cashmere goats

Item	Treatment diet			SEM	p-value
	Control	$ZnSO_4$	ZnMet		
DMI (g/d)	702	706	707	2.5	0.780
ADG (g)	35.7[b]	41.3[a]	42.7[a]	1.27	0.037
G/F (g/g)	0.051[b]	0.059[a]	0.060[a]	0.006	0.044
Cashmere length (cm)	3.02	3.05	3.03	0.083	0.895
Cashmere growth rate (mm/d)	0.50	0.51	0.51	0.138	0.895
Cashmere diameter (μm)	14.33	14.58	14.75	1.001	0.864

Means in the same row with different superscripts differ significantly ($p<0.05$).
SEM = Standard error of the mean.

RESULTS AND DISCUSSION

Performance and nutrient digestibility

Zn supplementation, regardless of source, increased ADG and G/F ($p<0.05$) during the experiment (Table 2), but no differences were noted between Zn sources ($p>0.05$). Limited research has evaluated the effects of Zn supplementation on growth performance in the goat. Similar to our results, Jia et al. (2008) found that ADG and G/F were increased when 15-45 mg Zn/kg DM were supplemented to a basal diet containing 22 mg Zn/kg DM in Liaoning Cashmere goats. Puchala et al. (1999) found that Zn supplementation significantly improved ADG in Angora goats.

No differences were observed in ADG between the two Zn sources. Results of previous studies indicated that growth performance did not differ in cattle supplemented with different Zn sources at a similar concentration to that used in the present study. Spears et al. (1991) reported no differences in ADG in calves supplemented with 25 mg Zn/kg DM of either ZnMet or ZnO. The addition of 25 mg of Zn/kg from Zn proteinate did not improve performance of steers fed a corn silage-based diet relative to ZnO-supplemented steers during the growing phase (Spears and Kegley, 2002). However, when Zn was supplemented at a relatively high level (120 mg Zn/d), goats fed ZnMet had higher ADG than those fed inorganic Zn (Puchala et al., 1999). These results corroborate with the findings of Wright and Spears (2004) who observed no differences between organic and inorganic Zn sources when Zn was supplemented at a relatively low level.

As shown in Table 2, DMI was not affected by Zn supplementation ($p>0.05$), which is in agreement with Puchala et al. (1999). They found that DMI of Angora goats was unaffected by Zn supplementation. Similarly, supplementation of Zn to a basal diet containing more than 25 mg Zn/kg DM had no effect on DMI in dairy goats (Salama Ahmed et al., 2003), growing lambs (Garg et al., 2008) and beef steers (Mandal et al., 2007).

Data on cashmere fiber characteristics are presented in Table 2. No differences ($p>0.05$) were observed among treatments for the length and diameter of cashmere fiber. Research evaluating the effect of Zn supplementation on fiber growth is limited, and results are not consistent. Jia et al. (2008) indicated that Zn supplementation did not affect the length and diameter of cashmere fiber in Liaoning Cashmere goats. However, a different result was observed by Puchala et al. (1999) who found that supplementation with 40 mg Zn/d (the basal diet containing 22 mg Zn/kg DM) improved mohair yield but did not affect mohair length and diameter in Angora goats. In addition, wool growth was increased in Merino sheep fed a diet containing 17 mg Zn/kg compared with 10 mg Zn/kg (White et al., 1994). In the current study, cashmere fiber growth and diameter were not affected by Zn supplementation. It is speculated that the level of Zn in the basal diet can support normal cashmere fiber growth in Cashmere goats, and supplementation above that level has no further impact.

No differences were noted in digestibility of DM, CP, EE and NDF among the treatment groups ($p>0.05$) as displayed in Table 3; however, ADF digestibility in the group supplemented with ZnMet was significantly higher

Table 3. Effects of source of supplemental Zn on nutrient digestibility of Cashmere goats (%)

Item	Treatment diet			SEM	p-value
	Control	$ZnSO_4$	ZnMet		
DM	63.5	63.6	62.6	1.55	0.676
CP	66.6	63.0	65.9	5.95	0.696
EE	60.1	59.2	62.1	3.45	0.762
NDF	53.3	52.5	51.4	2.61	0.637
ADF	51.4[b]	50.9[b]	54.6[a]	0.01	0.030

Means in the same row with different superscripts differ significantly ($p<0.05$).
SEM = Standard error of the mean.

Table 4. Effects of source of supplemental Zn on plasma mineral profile and AKP of Cashmere goats

Item	Treatment diet			SEM	p-value
	Control	$ZnSO_4$	ZnMet		
Zn (mg/L)	0.87[b]	1.14[a]	1.17[a]	0.15	0.001
Cu (mg/L)	0.84	0.69	0.70	0.03	0.057
Mn (mg/L)	10.51	11.28	11.12	0.56	0.239
Fe (mg/L)	39.87	42.93	43.86	5.33	0.587
AKP (U/L)	140.42[c]	171.75[a]	156.23[b]	156.13	0.008

Means in the same row with different superscripts differ significantly ($p<0.05$).
SEM = Standard error of the mean.

than in other groups ($p<0.05$). The unchanged digestibility of DM, CP, EE and NDF in the present study was not consistent with results in dairy goats (Salama Ahmed et al., 2003) which showed that Zn supplementation at 1 g/d (ZnMet) increased digestibility of DM, OM and CP. However, Mandal et al. (2007) and Garg et al. (2008) did not observe any effect on digestibility of DM, CP, EE and NDF due to Zn supplementation from organic and inorganic sources in steers and lambs, respectively. In agreement with the current experiment, an increase in digestibility of ADF was also found in a previous study in Muzaffarnagari male lambs (Garg et al., 2008), although the reason was not clear.

Plasma mineral profile and AKP

Plasma Zn was increased ($p<0.05$) and Cu tended to be decreased by Zn supplementation ($p = 0.057$), but no differences were found between Zn sources ($p>0.05$) (Table 4). Concentrations of Mn and Fe in plasma were not affected ($p>0.05$) by dietary treatments.

It was shown that plasma Zn concentration was increased by Zn supplementation. Chhabra and Arora (1985) reported that plasma Zn concentrations were higher in goats fed a basal diet (15 mg Zn/kg DM) supplemented with 65 mg Zn/kg DM than in control goats. Similarly, Garg et al. (2008) found that plasma Zn concentrations were higher in growing lambs fed a basal diet (34 mg Zn/kg DM) supplemented with 20 mg Zn/kg DM ($ZnSO_4$ or ZnMet) than in control lambs. In contrast, Greene et al. (1988) measured serum Zn on days 1, 28, 56, 84 and 112 of heifers fed no supplemental Zn or supplemental Zn (360 mg/d) from ZnO or ZnMet in a basal diet containing 81 mg/kg DM and reported no difference among treatments. Different responses to Zn supplementation may be related to differences in initial Zn status. Dietary Zn contents for the control (15 to 34 mg/kg DM) in these studies was lower than the 81 mg/kg DM used for steers in the study of Greene et al. (1988).

Cu is considered to be a major Zn antagonist. In previous studies (Mandal et al., 2007; Garg et al., 2008), supplementing 20 to 35 mg/kg DM of Zn to diets containing 32.5 to 34 mg of Zn/kg DM did not affect plasma Cu concentrations in beef steers and lambs. However, in the present study plasma Cu concentrations tended to be higher in the control group compared with goats supplemented with 20 mg of Zn/kg DM. This difference was probably due to the fact that the level of Cu (7.93 mg/kg DM) in the basal diet was lower than in the above studies (15.1 to 18.5 mg/kg DM).

Zn supplementation had no effect on plasma Fe and Mn contents. This is in agreement with findings in calves (Kincaid et al., 1997) and lambs (Garg et al., 2008). Kincaid et al. (1997) reported no difference in serum Fe of Holstein calves attributable to supplemental Zn source and level. Garg et al. (2008) did not find any effect on serum Mn levels in lambs on supplementation of 20 mg Zn/kg through different sources (ZnMet or $ZnSO_4$) to the basal diet containing 34 mg Zn/kg DM.

In our study, plasma AKP was improved by Zn supplementation ($p<0.05$) and was higher ($p<0.05$) in the $ZnSO_4$ than the ZnMet group. Blood AKP has been used as an indication of Zn status of animals. Khandaker and Telfer (1990) reported higher plasma AKP in Zn-adequate than Zn-deficient sheep. Spears (1989) showed that ZnO and ZnMet supplementation improved plasma AKP compared to control lambs and steers. The current results indicated that plasma AKP was greater in the $ZnSO_4$ than the ZnMet group. This agrees with Hatfield et al. (2001) who noted that serum AKP tended to be greater in sulfate- than in complex-supplemented ewes. These results indicate that organic Zn may be metabolized differently to inorganic forms.

Zn apparent absorption and retention

Data on Zn metabolism are presented in Table 5. The intake and faeces Zn were significantly higher ($p<0.05$) and apparent absorption rate was significantly lower ($p<0.05$) in both Zn supplementation treatment groups as compared to the control group, but no differences were noted between Zn sources ($p>0.05$). Similar to our results, Spears (1989) supplemented lambs fed a semi-purified diet with 5 mg of Zn/kg DM from ZnO or ZnMet and noted a similar apparent absorption of Zn for the two Zn sources and a low urinary excretion of Zn in lambs receiving ZnMet. In the same study, when 20 mg Zn/kg from ZnO or ZnMet was

Table 5. Effects of source of supplemental Zn on Zn apparent absorption and retention of Cashmere goats

Item	Treatment diet			SEM	p-value
	Control	$ZnSO_4$	ZnMet		
Zn intake (mg/d)	15.66[b]	29.84[a]	29.90[a]	7.00	0.001
Faeces Zn (mg/d)	11.84[b]	24.47[a]	24.62[a]	6.34	0.001
Urine Zn (mg/d)	0.41	0.41	0.39	0.41	0.087
Zn retention (mg/d)	3.41[b]	4.96[a]	4.88[a]	1.05	0.044
Zn apparent absorption rate (%)	24.40[a]	18.03[b]	17.65[b]	4.17	0.016

Means in the same row with different superscripts differ significantly ($p<0.05$).
SEM = Standard error of the mean.

added to an orchardgrass hay-based diet containing 30 mg Zn/kg, apparent absorption and retention of Zn was similar for both treatments, but urinary Zn was lower in lambs receiving ZnMet (Spears, 1989). These results indicate that $ZnSO_4$ and ZnMet may be metabolized differently in the body.

IMPLICATIONS

The results of this study indicate that $ZnSO_4$ and ZnMet are of similar availability based on performance in Liaoning Cashmere goats. Zn supplementation to a diet containing 22.3 mg Zn/kg DM diet increased growth performance in Cashmere goats during the cashmere growing period. Further research is needed to determine the Zn requirements of Cashmere goats.

REFERENCES

AOAC. 1990. Official methods of analysis, 15th ed. Assoc. Offic. Anal. Chem., Arlington, VA.

Bai, J. Y., Q. Zhang, J. Q. Li, E. J. Dao and X. P. Jia. 2006. Estimates of genetic parameters and genetic trends for production traits of Inner Mongolian White Cashmere goat. Asian-Aust. J. Anim. Sci. 19:13-18.

Chhabra, J. K. and S. P. Arora. 1985. Effect of Zn deficiency on serum vitamin A level, tissue enzymes and histological alterations in goats. Livest. Prod. Sci. 12:69-77.

Galyean, M., L. K. J. Malcolm-Callis, S. A. Gunter and R. A. Berrie. 1995. Effect of zinc source and level and added copper lysine in the receiving diet on performance by growing and finishing steers. Prof. Anim. Sci. 11:139-148.

Garg, A. K., M. Vishal and R. S. Dass. 2008. Effect of organic zinc supplementation on growth, nutrient utilization and mineral profile in lambs. Anim. Feed Sci. Technol. 144:82-96.

Greene, L. W., D. K. Lunt, F. M. Byers, N. K. Chirase, C. E. Richmond, R. E. Knutson and G. T. Schelling. 1988. Performance and carcass quality of steers supplemented with zinc oxide or zinc methionine. J. Anim. Sci. 66:1818-1823.

Hatfield, P. G., C. K. Swenson, R. W. Kott, R. P. Ansotequi, N. J. Roth and B. L. Robinson. 2001. Zinc and copper status in ewes supplemented with sulfate- and amino acid-complexed forms of zinc and copper. J. Anim. Sci. 79:261-266.

Jia, W. B., Z. H. Jia, W. Zhang, R. L. Wang, S. W. Zhang and X. P. Zhu. 2008. Effects of dietary zinc on performance, nutrient digestibility and plasma zinc status in Cashmere goats. Small Rumin. Res. 80:68-72.

Kincaid, R. L., B. P. Chew and J. D. Cronrath. 1997. Zinc oxide and amino acids as sources of dietary zinc for calves: Effects on uptake and immunity. J. Dairy Sci. 80:1381-1388.

Khandaker, Z. H. and S. B. Telfer. 1990. Treatment of zinc deficiency in sheep by zinc containing boluses. Asian-Aust. J. Anim. Sci. 3:53-59.

Mandal, G. P., R. S. Dass, D. P. Isore, A. K. Garg and G. C. Ram. 2007. Effect of zinc supplementation from two sources on growth, nutrient utilization and immune response in male crossbred cattle (*Bos indicus*×*Bos taurus*) bulls. Anim. Feed Sci. Technol. 138:1-12.

National Research Council. 1981. Nutrient requirements of goats. National Academy Press, Washington, DC.

Nunnery, G. A., G. E. Carstens and L. W. Greene. 1996. Feedlot performance and carcass characteristics in steers fed different sources and levels of supplemental zinc. J. Anim. Sci. 74(Suppl. 1):294 (Abstr.).

Puchala, R., T. Sahlu and J. J. Davis. 1999. Effects of zinc-methionine on performance of Angora goats. Small Rumin. Res. 33:1-8.

Salama Ahmed, A. K., G. Cajat, E. Albanell, X. Snch and R. Caslas. 2003. Effects of dietary supplements of zinc-methionine on milk production, udder health and zinc metabolism in dairy goats. J. Dairy Res. 70:9-17.

Shahjalal, M. D., H. Galbraith and G. H. Topps. 1992. The effect of changes in dietary protein and energy on growth, body composition and mohair fiber characteristics of British Angora goats. Anim. Prod. 54:405-412.

Spears, J. W. 1989. Zinc methionine for ruminants: relative bioavailability of zinc in lambs and effects of growth and performance of growing heifers. J. Anim. Sci. 67:835-843.

Spears, J. W., R. W. Harvey and T. T. Brown. 1991. Effects of zinc methionine and oxide on performance, blood characteristics, and antibody titer response to viral vaccination in stressed feeder calves. J. Am. Vet. Med. Assoc. 199:1731-1733.

Spears, J. W. and E. B. Kegley. 2002. Effect of zinc source (zinc oxide vs. zinc proteinate) and level on performance, carcass characteristics, and immune response of growing and finishing steers. J. Anim. Sci. 80:2747-2752.

SPSS. 1996. Statistical Packages for Social Sciences, Version 7.5. SPSS Inc., Chicago, IL, USA.

Underwood, E. J. and N. F. Suttle. 1999. In: The mineral nutrition of livestock, 3rd ed. CABI Publishing, CAB International,

Wallingford, Oxon, UK.

Van Soest, P. J., J. B. Roberston and B. A. Lewis. 1991. Methods for dietary fiber NDF and non-starch polysaccharides in relation to animal nutrition. J. Dairy Sci. 74:3583-3597.

White, C. L., G. B. Martin, P. I. Hynd and R. E. Chapman. 1994. The effect of zinc deficiency on wool growth and skin and wool follicle histology of male Merino lambs. Br. J. Nutr. 71:425-435.

Wright, C. L. and J. W. Spears. 2004. Effect of zinc source and dietary level on zinc metabolism in Holstein calves. J. Dairy Sci. 87:1085-1091.

Zhang, W., R. L. Wang, X. P. Zhu, D. O. Kleemann, C. W. Yue and Z. H. Jia. 2007. Effect of dietary copper on ruminal fermentation, nutrient digestibility and fiber characteristics in cashmere goats. Asian-Aust. J. Anim. Sci. 20:1843-1848.