# Trace Mineral Supplementation: What are our Targets?

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Trace minerals are indirectly or directly associated with a tremendous variety of metabolic processes. Deficiency diseases affect almost every physiologic function and include immune dysfunction (Cu, Zn, Se); developmental abnormalities (Cu, Mn, I); abortion (Cu, I, Se, Zn); retained placenta (Cu, Se, I); and metabolic disturbances (Co, Fe, Zn, I). Although there are not an overwhelming number of published reports of various trace mineral deficiency or toxicity diseases in llamas and alpacas; clinical and empirical evidence suggests they are susceptible to trace mineral diseases like other ruminant species (Van Saun, 2006a; Van Saun, 2009). Copper toxicity is the most frequently reported trace mineral disease in llamas and alpacas. Even though mineral supplements account for the smallest fraction of the total diet, more time and effort is expended by owners in deciding which mineral supplement, if any, is best in their feeding program. To determine adequacy of a given nutritional supplement we need two pieces of information, nutrient requirements of the animal and nutrient analysis of forages being fed. The latter point is one that is often overlooked and not appropriately utilized. However, the first point is most critical as it does not matter how much mineral is in forage if one does not have some perspective as to how this forage matches with the animal's requirement. Feeding recommendations for most domesticated animal species are based on nutrient requirements established by the National Research Council (NRC). Most recently the NRC published a report describing nutrient requirements for small ruminants, including llamas and alpacas (NRC, 2007). Unfortunately the NRC publication did not provide suggested requirements for trace minerals in llamas and alpacas with the exception of selenium. This presentation will review methods and challenges in defining trace mineral requirements and provide some new perspectives on trace mineral requirements of llamas and alpacas based on the new NRC data.

**Defining trace mineral requirements**

The maintenance requirement for an essential nutrient defined as the amount needed to be consumed over a time period (typically daily) that will maintain normal body functions and result in zero net nutrient balance (i.e., no loss or gain). Nutrient requirements can be further defined relative to additional amounts needed to support various physiologic states present in a given animal. Controlled feeding trials are the gold standard for determining trace mineral requirements, though they are very intensive and difficult trials to run. Total fecal collections in animals fed a minimal amount of a specific mineral allow one to determine endogenous losses in defining the maintenance requirement. Total fecal and urinary collections in animals fed varying amounts of a defined mineral from specified feed ingredients are used to determine mineral availability. Measurement of mineral concentrations in fetus, placenta and uterine tissues (pregnancy), milk (lactation), body tissue (growth) or sweat (work or activity) are used to determine net mineral requirement in support of these specific physiologic conditions. The required daily amount of trace mineral consumed in the diet must be sufficient to support all present physiologic states of a given animal and account for availability of the mineral source(s) in the diet.

Models describing an essential nutrient's requirement can be empirical (based on amount per kg body weight, metabolic body weight or dry matter intake) or mechanistic. Mechanistic models describe specific components of a requirement, for example, nitrogen loss in urine, feces and skin exfoliation are used to estimate maintenance protein requirements of cattle. These obviously are more precise requirement models, but more difficult to determine. When the data are available, the NRC prefers to characterize nutrient requirements using factorial mechanistic models. A factorial approach entails having either an empirical or mechanistic estimation model for each physiologic state. Using the factorial approach, the total nutrient requirement for a given animal is the sum of all its physiologic states. For example, if an animal was pregnant and still growing, the total requirement would be the sum of maintenance, growth and pregnancy and modified by rate and composition of gain and duration of pregnancy.

The most recent NRC publication addressing nutrient requirements for small ruminants has taken a number of approaches in defining trace mineral requirements. Sufficient data were available to use a factorial approach for sheep trace mineral requirements, but goats, cervids and camelids are primarily based on empirical models. Maintenance is determined by body weight and mineral content of wool or hair. Pregnancy requirement is based on expected total birth weight and lactation on daily milk yield. Some trace minerals, namely cobalt and iodine, remain as a requirement based empirically on dietary intake (part per million [ppm]).

Although Van Saun (2003; 2006b) had provided some extrapolated models to estimate trace mineral requirements for llamas and alpacas (Table 1), these models were not based on animal feeding trials and were not included in the NRC (2007) publication. Models by Van Saun (2003; 2006b) were extrapolated from mineral recommendations for beef cattle (NRC, 2000), sheep (NRC, 1985) and goats (NRC, 1981) by averaging calculated requirements on µg or mg per kg body weight basis. The small ruminant NRC (2007) makes no recommendation for trace mineral requirements respective to llamas and alpacas with the exception of selenium. The suggested selenium recommendation was based on a single survey study (Herdt, 1995). In this study the average selenium supplementation rate was 0.74 mg/day, which was adopted as the recommendation by the NRC. However, the study suggested a supplementation rate of 1 mg/day to llamas was associated with adequate selenium status of female and cria, based on blood selenium concentrations. This recommendation makes no adjustments for body weight differences between llamas and alpacas, nor does it account for physiologic state. For the other trace minerals, the NRC (2007) publication recommends that requirements for sheep be used. Clearly more evidence-based data, ideally feeding trials, are needed to better define daily mineral requirements of llamas and alpacas. Where do we go from here?

**Confounding issues in defining trace mineral requirements**

In approaching a method to describe new models to predict trace mineral requirements for llamas and alpacas, a number of confounding issues need to be addressed.

***Dry matter intake***. When we describe nutrient requirements they can be characterized on a nutrient density (%, ppm) or totals (g/day, mg/day) basis. It is much easier to communicate nutrient requirements on a nutrient density basis as opposed to amounts per day. However, it must be remembered that animals only eat amounts of nutrients and not percentages! When describing dietary nutrient content on a density basis, one needs to consider dry matter intake and how it impacts daily nutrient intake. This is a concern when extrapolating nutrient requirements from cattle, sheep or goats to camelids. Van Saun (2003; 2006b) had accounted for a lower dry matter intake in extrapolating averaged requirements from beef cattle, sheep and goats to llamas and alpacas.

**Table 1.** Previously suggested llama and alpaca micromineral requirements for differing physiologic states, based on data derived from beef cattle, sheep and goats (from Van Saun, 2006b with permission).

| Nutrient | Averaged Requirement[1] | Extrapolated Requirement | | | MTL[5] |
|---|---|---|---|---|---|
| | | Daily Intake[2] | Diet[3] | Group[4] | |
| Cobalt | 1.76 µg/kg BW | 0.11 - 0.28 mg/d | 0.12 - 0.14 | M, G, P, L | 10 |
| Copper | 0.15 mg/kg BW | 9 - 24 mg/d | 9 - 12 | M, G, P, L | 30 |
| Iodine | 9.5 µg/kg BW | 0.57 - 1.5 mg/d | 0.6 - 0.76 | M, G | 50 |
| | 16 µg/kg BW | 0.96 - 2.6 mg/d | 1.1 - 1.3 | P, L | |
| Iron | 0.7 mg/kg BW | 42 - 1120 mg/d | 47 - 56 | M | 500 |
| | 0.9 mg/kg BW | 54 - 144 mg/d | 60 - 72 | G, P, L | |
| Manganese | 0.36 mg/kg BW | 21.6 - 57.6 mg/d | 24 - 29 | M, G | 1000 |
| | 0.8 mg/kg BW | 48 - 128 mg/d | 53 - 64 | P, L | |
| Selenium | 5.3 µg/kg BW | 0.3 - 0.85 mg/d | 0.35 - 0.42 | M, G | 5 |
| | 6.0 µg/kg BW | 0.36 - 0.96 mg/d | 0.4 - 0.48 | P, L | |
| Zinc | 0.53 mg/kg BW | 31.8 - 84.8 mg/d | 35 - 45 | M, G | 500 |
| | 0.67 mg/kg BW | 40.2 - 107 mg/d | 45 - 54 | P, L | |

[1]Extrapolated from nutrient requirements for beef cattle (NRC, 1996), sheep (NRC, 1985) and goats (NRC, 1981a).
[2]Estimated daily requirement based on a range of adult body weights from 60 to 160 kg.
[3]Dietary concentration (mg/kg) on dry matter (DM) basis. Nutrient density calculations based on an assumed range of DM intake between 1.25 and 1.5% of body weight.
[4]Physiologic states of maintenance (M), growth (G), lactation (L), and pregnancy (P) for which the requirement is defined.
[5]Maximum tolerable level (mg/kg), defined as largest dietary concentration of a given mineral that could be fed for short periods (3 mo) without problems. Based on data from NRC, 2005.

***Body weight differences***. Although llamas and alpacas are very similar, the two species populations have different, but slightly overlapping, body weight range. Adult body weight differences result in slightly higher intake capacity on a body weight basis in alpacas compared to llamas (Lopez and Raggi, 1992). The NRC does not account for any difference in intake between llamas and alpacas. Body size differences can also result in altered rates of passage that could impact mineral availability. Trace mineral models for goats are not the same as sheep for all minerals, due to specific documented requirement differences, especially copper. Comparing trace mineral requirements per kg of body weight or metabolic body weight basis, might provide a better method of adjusting for differences in intake capacity and body size.

***Mineral availability***. A new approach adopted by the NRC is to account for mineral availability from feed ingredient sources in estimating daily dietary mineral content capable of meeting the daily requirement. For example, if the net requirement for a mineral is 15 mg/day and the mineral is 15% available from all dietary sources, then the diet must contain 100 mg (15/.15) of the mineral. There may be differences in mineral availability between forage and mineral supplements, or within mineral supplements. Availability of dietary zinc (0.15) and manganese (0.0075) is considered equal between sheep and goats. Again, no data are currently available for llamas and alpacas. In making new requirement models, either one would have to exclude mineral availability from new models, or assume equality with other species where appropriate.

**New models for llamas and alpacas**

All evidence suggests that llamas and alpacas require trace minerals to maintain normal body functions and there does not seem to be significant differences in these requirements compared to other species. Relative to copper, llamas and alpacas are more similar to sheep than beef cattle or goats. Similar to what had been completed previously (Van Saun, 2003; 2006b), the author has used the new NRC (2007) models for trace mineral requirements of sheep and goats in comparison to beef cattle (NRC, 2000) to evaluate potential modifications to previous models or develop newer models in predicting llama and alpaca trace mineral requirements. Direct utilization of NRC (2007) sheep models were compared to extrapolated empirical models based on either kg body weight or metabolic body weight. The following are preliminary recommendations for the key trace minerals.

***Cobalt***. Requirement for cobalt was equivalent across species at 0.1 mg/kg dry matter intake. No modifications were made for differing physiologic states. Calculated cobalt requirement on a µg/kg body weight was 1.65, 1.78 and 2.01 for sheep, cattle and goats, respectively. Using metabolic body weight, sheep, goats and cattle cobalt requirements were 4.9, 5.3 and 8.4 µg/kg, respectively. To achieve similar intakes accounting for differences in intake capacity, recommended cobalt requirement for llamas and alpacas was between 0.12 and 0.15 mg/kg dietary dry matter. The higher level would best fit animals with lower intake. There is no difference for different physiologic states.

***Copper***. Camelids are more sensitive to copper toxicity, similar to sheep. Copper requirements for goats and cattle are much higher comparatively, and most likely not appropriate for camelids. The sheep copper requirement for maintenance is based on endogenous losses and copper content of fleece. Using camelid values in the sheep equation results in copper requirements per kg body weight or metabolic body weight that are lower than for sheep. Using a requirement of 0.12, 0.15 and 0.18 mg/kg of body weight for maintenance, pregnancy and lactation, respectively, provides similar values to the sheep model.

***Iodine***. Requirements for iodine were also based on dietary concentration across species. Using similar calculations, recommendations for llamas and alpacas are 0.55 to 0.65 mg/kg dietary dry matter for maintenance and pregnancy and 0.65 to 0.75 mg/kg dietary dry matter for lactation.

***Iron***. Requirement for iron is based on dietary concentration for goats and cattle. The sheep model has a lower requirement compared to the other species on per kg body weight or metabolic body weight basis. A dietary concentration of 35 to 40 mg/kg dietary dry matter is recommended for llamas and alpacas for maintenance, pregnancy and lactation.

***Manganese***. Both sheep and goat models suggest an endogenous loss of 2 µg/kg body weight. The sheep model also includes manganese lost to wool. The average requirement across species per kg body weight is 0.33 mg/kg. To achieve this level a suggested dietary concentration of 22 to 25 mg/kg dietary dry matter is required for maintenance. Suggested pregnancy requirement is slightly higher, 28-30 mg/kg, while the lactation requirement is similar to the maintenance requirement.

***Selenium***. The selenium requirement model is quite confusing. The sheep model predicts very low daily intakes (0.03-0.11 mg/day). The sheep requirement calculated as µg/kg body weight is much lower (1.1 µg/kg) compared to cattle (5.3 µg/kg) or goats (7.0 µg/kg). A requirement of 6.5-6.8 µg/kg body weight would provide selenium at a rate consistent with the NRC (2007) and Herdt (1995) recommendation. A slightly higher requirement of 7.0-7.5 µg/kg would be recommended for pregnant and lactating animals.

***Zinc***. Although mineral availability is considered the same for sheep and goats, endogenous losses of zinc are quite different according to NRC (2007) models. There is also a significant amount of zinc in wool of sheep; making the requirement higher relative to goats. Given the documented health issues associated with zinc in camelids, it seems prudent to err on the higher side relative to requirements. To achieve similar mg/kg body weight values for camelids, a dietary concentration of 45, 55 and 60 mg/kg is suggested for maintenance, pregnancy and lactation, respectively.

## Summary

Trace mineral requirements for llamas and alpacas are not well defined and the recent NRC report did not provide strong guidance on suggested requirements. Requirements for sheep were suggested to be appropriate for llamas and alpacas. This is reasonable for some minerals, but not for all, based on clinical and observational data. Feeding trials are needed to more definitively describe daily trace mineral requirements. A similar approach as previously employed in averaging requirements across species was used with the new sheep and goat requirements to further refine some feeding guidelines for llamas and alpacas.

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