Understanding Feed Supplements to Properly Balance Alpaca Diets

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Take Home Messages:

- Supplements are needed to balance daily nutrient needs not met by forages
- Supplement feeds usually contain trace minerals and vitamins, but may also contain variable amounts of energy, protein and fiber
- Feed tag information can be useful to discriminate between products
- Nutrient content and intake amount determines net nutrient delivery from a given supplement
- Supplements vary tremendously in their nutrient delivery and they must be appropriately matched to the forage feeding program

Forage Quality and Need for Supplements

Forages are the foundation of an alpaca's nutritional program. Unfortunately, forages are most variable in nutrient composition as a result of various factors influencing their composition (i.e., plant species, stage of growth, soil fertility, and management practices). A survey from Kansas State University reported forage analysis findings from 709 samples obtained from 23 states. These data showed a large proportion of the forages were either marginally deficient or deficient in zinc (77%), selenium (69.5%) and copper (66.7%) [Mortimer et al., 1999]. Most forages grown across the United States are deficient in zinc (<25 ppm). If legume hays are being fed then calcium excess is present, which may further exacerbate zinc deficiency. Iron content of most forage is high, which can interfere with copper, zinc and selenium availability. Another notable difference is the excessive amount of potassium in all forages relative to requirement. High dietary potassium can interfere with magnesium availability in ruminant animals. Supplementation with vitamins A, D and E will depend upon the forage type and quality. Pasture is sufficiently high in vitamins A and E, whereas stored hay is commonly low in all vitamins [Dart et al., 1996]. Clearly additional sources of minerals and vitamins through a supplement feed are necessary to balance out a forage feeding program for llamas and alpacas.

There are many commercial products on the market that provide minerals, vitamins and potentially other nutrients and additives but, how does one decide which is right for their 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. With this information, total nutrient delivery from forages can be compared to requirements. The difference must then be accounted for in the supplement feed. If the supplemental feed can deliver the desired amount or more in the consumed amount, then it would be an acceptable product. If it does not at least equal the difference between requirement and nutrient intake from forage, then it is an inadequate feed supplement.

Feeding recommendations for most domesticated animal species are based on nutrient requirements established by the National Research Council (NRC) [NRC, 2007]. Unfortunately there are no mineral requirement recommendations, with the exception of selenium, in the recent NRC publication addressing nutritional requirements of llamas and alpacas. These missing data are a result of an information void relative to research documenting mineral requirements for llamas and alpacas. Most mineral recommendations are extrapolated data from sheep, goats or cattle [Van Saun, 2003; 2006]. The objective of this presentation will be to address producer concerns in how to decide adequacy of dietary supplements available for New World camelids with special emphasis on copper and selenium nutrition.

Why are Minerals and Vitamins Needed?

Minerals are inorganic elements classified into two groups, macrominerals or microminerals (trace minerals), based on daily amounts required. Macrominerals are required in grams (g) or ounces (oz) per day and include calcium (Ca), phosphorus (P), magnesium (Mg), sodium (Na), chlorine (Cl), potassium (K) and sulfur (S). Macrominerals are primarily responsible for bone structure, osmotic (fluid balance) regulation, nerve conduction and acid-base balance among others. Trace minerals are required in milligrams (mg) per day and include cobalt (Co), copper (Cu), iodine (I), iron (Fe), manganese (Mn), selenium (Se) and zinc (Zn). 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); retained placenta (Cu, Se, I); and metabolic disturbances (Co, Fe, Zn, I).

Fat-soluble vitamins, namely vitamins A, D and E, are the most important for camelids and should be supplemented in the diet, especially a hay-based diet. Vitamins A and E will be adequately ingested if llamas and alpacas are grazing on fresh pasture. However, when fed stored, sun-cured hay, vitamins A and E may be insufficient. In contrast, vitamin D is very low in pasture but is higher in sun-cured forages although possibly not high enough to meet needs without supplementation.

Vitamin E is an antioxidant, which works in concert with selenium in protecting the cell from oxidative damage and modulates immune function. Vitamin A is also an antioxidant, but has many additional metabolic functions including maintaining normal epithelial development and health, bone remodeling, vision and immune function. Vitamin D is a critical nutrient for calcium and phosphorus balance and bone development. Vitamin D deficiency has been implicated in a hypophosphatemic rickets syndrome of young growing crias [Van Saun et al., 1996].

Feeding Recommendations: Copper

One needs to provide sufficient amounts of Cu from the diet without greatly exceeding the requirement and potentially inducing toxicity. The challenge here is remembering dietary Cu is contributed by every ingredient fed to some extent. This is where many people become confused. Based on current information, daily estimated Cu requirement on a dietary concentration basis is between 9 and 12 ppm. However, many feed ingredients can contain much higher Cu content, for example mineral supplements might contain between 30 and 600 ppm Cu. Does this mean these feed ingredients are toxic? Possibly, but only if they were fed as a sole feed source (not practical or realistic) or in combination with other feed ingredients with high Cu content. Each feed ingredient will contribute to the overall total dietary Cu content, but only to the proportion of the total diet the individual feed represents.

In Table 1, a number of examples are provided to demonstrate the concept of ingredient contribution to dietary Cu content. For these examples, three feed ingredients (hay, pellet, and mineral) comprise the total diet. The same amount of hay (1.7 lbs/day), pellet (0.25 lb/day), and mineral supplement (0.015 lb/day or 0.25 oz/day) are provided in each example for simplicity and only Cu content is varied. In these examples it can be seen that hay provides the largest amount of dietary Cu even though it has the lowest Cu content. This is a direct result of hay being the largest proportion of the total diet. Example 1 shows Cu intake (11.93 mg/day) and dietary content (13.4 ppm) are in line with estimated requirements (9 mg/day; 10 ppm) for the defined animal (see table legend).

Table 1. Contribution of individual feed ingredients (hay, pellet, mineral supplement) to total dietary copper (Cu) content. For comparison in the following examples daily Cu requirement for a 132 lb adult llama is 9 mg/day. Dietary Cu content can vary from 9 to 12 ppm assuming a total intake of 1.5 and 1.25% of body weight, respectively.

Example 1	**Forage**	**Pellet**	**Mineral**	**Total Diet**
Intake, lb/day	1.7	0.25	0.015	1.97
Cu, ppm	9.0	26	300	13.4
Cu, mg/day	6.9	2.95	2.04	11.93
Example 2	**Higher pellet Cu content**			
Intake, lb/day	1.7	0.25	0.015	1.97
Cu, ppm	9.0	46	300	15.9
Cu, mg/day	6.9	5.22	2.04	14.2
Example 3	**Lower mineral Cu content**			
Intake, lb/day	1.7	0.25	0.015	1.97
Cu, ppm	9.0	26	30	11.32
Cu, mg/day	6.9	2.95	0.20	10.1
Example 4	**Higher forage Cu content**			
Intake, lb/day	1.7	0.25	0.015	1.97
Cu, ppm	25	26	300	27.23
Cu, mg/day	19.28	2.95	2.04	24.27

In example 2, the pellet Cu content is increased from 26 to 46 ppm, yet dietary Cu intake and content are not greatly increased. Some are concerned about the Cu content of the mineral supplement, yet example 3 shows the mineral Cu reduced from 300 to 30 ppm, but Cu intake is reduced only by 2 mg/day. Of greatest concern is the situation in example 4 where hay Cu content increases from 9 to 25 ppm. In this situation, daily Cu intake and dietary content is greatly increased and, depending upon dietary Mo status, could potentially lead to Cu toxicity problems. Hay Cu content typically is between 4 and 14 ppm, though much higher Cu concentrations are being observed more frequently in many regions of the U.S. High forage Cu content may be the result of inappropriate fertilization practices, especially if poultry or pig manure are used. Dietary Cu is very high in poultry and pig diets, which accounts for the higher manure Cu content. Another concern is the use of copper sulfate footbaths on dairy cattle farms and the spread of this material on croplands. Given these situations, it is important for you to know just how the forages you purchase are raised or you need to test your forages to assess Cu status.

Given these dietary examples, it is imperative that all potential sources of Cu be accounted for in the diet to ensure adequate, but not excessive, Cu is consumed. As previously described, dietary Mo is an important factor to address in assessing dietary Cu status. From these examples both dietary ingredient Cu content and intake amount need to be considered. If testing feed ingredients for Cu content, one should also have Mo and S content determined. In feeding appropriately for Cu, one should first evaluate forage Cu content then match pellet and mineral supplement accordingly. If your pellet product contains more than 50 ppm Cu, then you may wish to use a mineral supplement with low (<100 ppm) Cu. If your hay has a Cu content greater than 15 ppm, then you may need to feed a pellet with lower Cu content and a low Cu mineral. It must be remembered that high dietary Cu intake does not guarantee that a toxicity event will occur. Most reported toxicity cases are associated with dietary Cu content exceeding 25 to 30 ppm and a high (>16:1) Cu to Mo ratio [Pugh, 1993].

Feeding Recommendations: Selenium

Inherently there is some Se content to all feed ingredients, but this is extremely variable depending upon ingredient and geographic origin. With llamas and alpacas, the primary feed ingredient is forage with supplemental concentrate (pellets, mineral, or both). Forage Se content is extremely variable across all of North America and dependent upon soil conditions. Selenium content of the soil is variable (ranging from < 0.1 to > 80 ppm) and soil acidity, rainfall amount, and other factors can greatly influence its availability to plant tissues. Acid soil conditions, heavy rainfall, and presence of inhibiting substances (iron and aluminum) will result in very low plant Se content. Essentially the eastern coast, north to south, over to the Great Lakes region and the entire western coast areas are low (< 0.1 ppm) in forage Se content. The central plains states from North Dakota south through Texas have mixed selenium status. Regions of Colorado have deficient (eastern side) or adequate (central to western areas) with pockets of high selenium content. Although difficult, forage Se content can be determined at some forage testing laboratories. Given the variability in selenium content in Colorado, it would behoove owners to have forages tested for selenium content to best manage their mineral or pellet feeding strategies.

Free choice mineral products can range widely in Se content; from minimal (0 ppm) up to the legal maximum (90 ppm for sheep; 120 ppm for cattle). What you are interested in is the total amount consumed. To assess mineral adequacy relative to Se, one needs to determine the Se content of the mineral and daily animal intake. Mineral Se content can be determined from the feed tag with the product. Selenium content may be expressed as ppm (mg/kg) or as a percent (%). To convert percent to ppm, move the decimal point to the right 4 places. For example, 0.005% Se is the same as 50 ppm. The bigger challenge is determining average daily mineral intake. Mineral intake is controlled by salt content of the mineral product. Most products will have some intake guidelines on their feed tag. However, expected intake is often over estimated.

Mineral intake will be variable over time, but typically llamas and alpacas can be expected to consume between 0.25 and 0.33 ounces per day. Again, it is best to determine this for your animals. Also, do not have both white salt and a trace mineral salt available for the animals to choose. They only seek out a salt source. Armed with intake and Se content information, you can then use Table 2A to assess Se adequacy. In reviewing this table, the highlighted cells show the combination of mineral Se content and intake that achieves at least 1 mg Se intake per day. From these data it can be seen that only mineral that has at least 90 ppm Se will achieve near 1.0 mg Se intake with a daily mineral intake less than 0.5 oz per day. Many of the commercial mineral products contain less than 90 ppm Se.

Another method of supplementing Se is through the pellet or grain supplement. Using the data shown in Table 2B, one can determine a reasonable Se concentration for their pellet or grain product. If we set 1.0 mg Se/day as the goal (highlighted row in Table 3B), read across the row to see how many pounds of concentrate would need to be fed to achieve this Se intake amount. The variation is due to the different concentration of Se in the pellet or concentrate product. In this table the Se concentration of the pellet or concentrate is varied from 0.3 to 8 ppm. It is only when you have a Se concentration of 2.0 ppm or greater where you would be feeding 1 lb or less of the pellet or concentrate product to achieve the desired 1.0 mg Se/day delivery rate. These two examples demonstrated how one could provide the entire supplemental Se allotment from either mineral or pellet sources. Be careful not to provide both sources and potentially double the amount of supplemental Se.

Table 2. Calculated amounts of either selenium intake from free-choice mineral supplements (A) or selenium-fortified pellet supplement (B) needed to achieve specified levels of selenium intake. These calculations are assuming there is no selenium being contributed from the forage.

A. Free Choice Mineral Supplements					
Selenium Mineral Content (ppm)	**Daily Salt Intake (oz)**				
	0.25	**0.33**	**0.5**	**1.0**	**1.25**
	Amount of Selenium (mg/day) consumed				
30	0.21	0.28	0.4	0.85	1.1
50	0.35	0.47	0.7	1.4	1.8
70	0.50	0.66	1.0	2.0	2.5
90	0.64	0.84	1.3	2.6	3.2
120	0.85	1.12	1.7	3.4	4.25

B. Selenium Containing Pellet or Grain Supplements					
Desired Selenium Intake	**Supplement Selenium Concentration (ppm)**				
	0.3	**1.0**	**2.0**	**4.0**	**8.0**
mg/day	*lbs supplement needed to be consumed per day*				
0.5	3.7	1.1	0.6	0.3	0.15
0.75	5.5	1.7	0.8	0.4	0.20
1.0	7.3	2.2	1.1	0.55	0.27
1.5	11.0	3.3	1.7	0.85	0.43
2.0	14.7	4.4	2.2	1.1	0..55
2.5	18.4	5.5	2.8	1.4	0.7

Potential problems with Se toxicity are recognized; is there a concern with oral supplementation? Nonruminant animals such as pigs and horses absorb Se from the diet very efficiently and hence are susceptible to toxicity problems. The maximal tolerable level for Se in the total diet of nonruminants is 2 ppm or about 10x the requirement. Remember, this is the total diet consumed and not a single ingredient. In contrast, ruminant animals, including llamas and alpacas, are less efficient at Se absorption due to rumen alteration of the Se molecule. Though not determined directly for llamas and alpacas, maximum tolerable level for Se in ruminant diets is considered 5 ppm or even higher. This means that ruminant animals, including llamas and alpacas, are less susceptible to Se toxicity, but with excessive supplementation it can happen. There are still many questions to be answered relative to Se supplementation in llamas and alpacas.

Evaluating Supplement Adequacy

The ideal supplement would be one that is readily consumed (palatable), has a nutrient content to complement the forage program and is consumed at a rate sufficient to meet the desired intake of all nutrients. Most supplements are purchased on the basis of word of mouth from other producers, based on their experience, or whatever is available at the local feed store. Given that your animal's health and productivity and farm profitability are dependent upon the nutrition program one needs to obtain as much information about a particular product as possible. There are a number of methods that can be used to evaluate appropriateness of a supplement for your feeding program. These include test feeding for palatability to determine level of acceptance; interpreting and comparing feed tag information; calculations of nutrient delivery compared to requirements and determinations of nutrient balance between forage and supplement compared to desired dietary nutrient density.

Feed Tag Interpretation. Supplements vary tremendously in their nutrient content. Some of this variation is intentional relative to the designed purpose of the product. Mineral supplements are usually salt-based, to limit intake, and then contain variable concentrations of trace minerals and possibly fat-soluble vitamins. These are your classic trace mineral salt products, which are typically fed free-choice. Complete mineral products will also contain calcium, phosphorus and other macrominerals. These products may be free choice or designed to be fed at a defined rate. Other supplements will contain energy and protein sources and are identified as "complete grains or supplements". This means the supplement contains all other nutrients needed to complement the forage being fed. Expected intake for these products will vary according to formulated nutrient density.

Feed tags on commercial products are required by state law to provide designated information about the product. This includes feed name, purpose, feeding directions, manufacturer's address, guaranteed analysis, list of ingredients, medications (if present) and withdrawl time (if medicated). The required guaranteed analysis provides limited analyses, usually crude protein, crude fiber, crude fat, calcium, phosphorus and possibly salt and ash. Other product literature may be available with more details and some companies will provide more detailed information on their feed tags. Feed tag information generally does not provide you energy content. Guaranteed analysis values are on an as fed basis and not dry matter.

Reviewing the ingredient list on the feed tag can provide some insight as to potential energy sources. Ingredients like corn, oats and barley will provide much carbohydrate for energy.

Fiber sources, which can provide some energy, include wheat middlings, wheat bran, soybean hulls, cottonseed hulls or forage products (generic by-product term). Protein sources will include primarily soybean, canola or corn gluten meals. The first 3 ingredients generally set the trend for the product. To really have a good understanding of what a particular supplement product contains, one needs to have a sample analyzed for nutrient content through a certified feed analysis laboratory. Ideally, forage should also be sampled for nutrient content for best evaluation, but averaged nutrient content from tables can be used as a guide. If forage testing is not completed, one should err on the higher side for desired nutrient delivery from supplements.

As for mineral supplementation sources, inorganic sources from sulfate and carbonate forms are usually more bioavailable than the oxide forms. Review the list of ingredients to see what mineral sources are being used. Organic forms of minerals are protected from pregastric alteration and generally are considered highly available. However, there is more than one form of organic minerals and not all forms result in positive supplementation responses. Overall, organic forms of minerals are more expensive than their inorganic counterparts. Organic forms are best used in situations of stress or reduced intake capacity. A good example is zinc. Clinically there seems to be a zinc-responsive dermatosis problem with domesticated camelids. Improvements in the condition have been observed when zinc methionine (ZinPro®) has been supplemented.[6]

Other ingredients may also be included in a supplement. Generally these are stabilizers, preservatives and feed additives. Typical additives may include yeast cultures or yeast extract, probiotic products, various B-vitamins, yucca and many other substances. Data to support the incorporation of many of these feed additives is very limited. As with other ruminants, it is hypothesized that all necessary B-vitamins (water-soluble) are synthesized by bacteria in the forestomach and therefore are not required in the diet. However, under certain stress conditions or fermentation disorders, B-vitamin supplementation may be beneficial. Yeast products have been shown to have a positive effect on rumen fermentation, intake and resistance to heat stress in cattle. Similar positive responses may be applicable to camelids. Supplements should not be purchased solely on the basis of whether or not these additive products are included.

Nutrient Delivery Calculations. Another aspect of evaluating a supplement is determining the amount of nutrient delivered relative to animal requirements. For this you need to be able to interpret and use the information presented on the product feed tag. The difficult part here is interpreting and comparing nutrient concentrations of differing products based on label information. You need to compare “apples with apples”; therefore, you must carefully read label information and convert information to an equivalent basis for comparison. For example, nutrient content of a product may be presented on a per pound basis, per ounce basis or per dose basis. These are not necessarily the same for all products. Nutrient content may be presented as a percent or part per million (ppm). Table 3 provides some basic conversion factors helpful in comparing and using label nutrient values.

One method would be to calculate total amount of a given nutrient that would be consumed from the supplement and then compare this value to extrapolated nutrient requirements. For a given nutrient, multiply amount fed (as fed or dry matter basis) times nutrient content (as fed or dry matter basis, respectively). If your supplement meets each of these nutrient requirements without accounting for the forage, then you can assume the supplement is adequate. If the supplement does not meet the suggested requirement, then determine if sufficient amounts of the nutrient in question are available from the forage. In general, forages provide very little additional trace minerals, except for iron and manganese. This method requires a fair amount of calculations and this process could be greatly enhanced by using a computer spreadsheet.

Table 3. Common nutritional conversion factors.

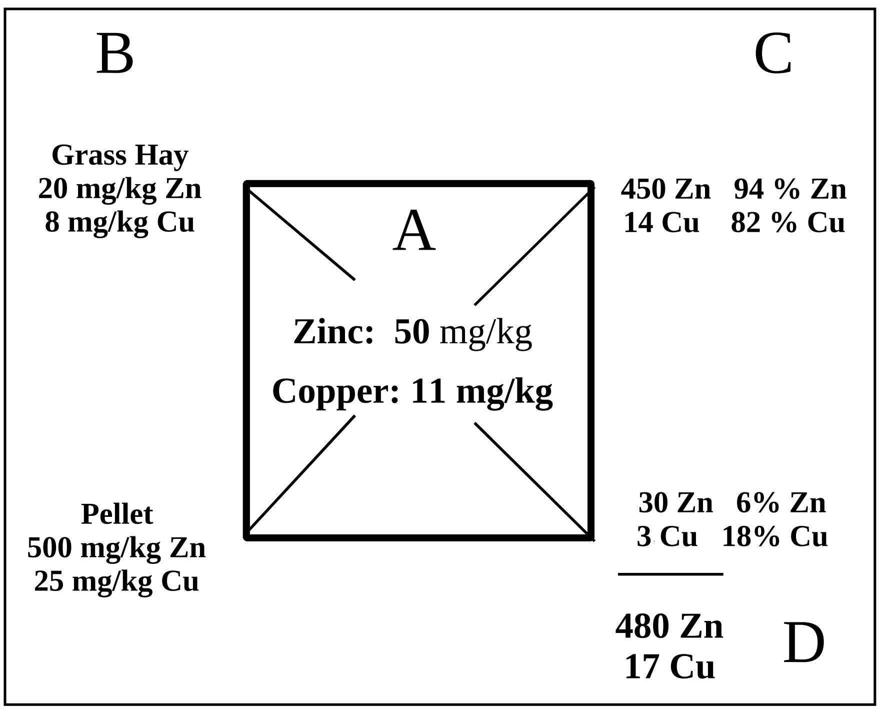
Units Given	Units Wanted	Conversion
oz	grams	multiply by 28.4
lb	grams	multiply by 454
lb	oz	divide by 16
grams	mg	move decimal to right 3 places
mg	grams	move decimal to left 3 places
mg	µg	move decimal to right 3 places
mg/kg	ppm	same value
mg/kg	mg/lb	multiply by 0.454
mg/kg (ppm)	%	move decimal to left 4 places
%	mg/kg (ppm)	move decimal to right 4 places

Supplement-Forage Compatibility. The second step in evaluating supplement adequacy is to determine how well the supplement nutrient profile complements the forage nutrient profile. A method of assessing nutritional compatibility between a supplement and forage is to use a Pearson Square calculation method. The Pearson Square is a method used to determine how to combine two feed products to achieve a desired nutrient content. For the example shown (Figure 1), you would need to feed 94% grass hay with 6% pellet to balance the diet for zinc. In contrast, you need to feed 82% grass hay and 18% pellet to balance the diet for copper. To put this in better perspective, if the animal will consume 1.5% of body weight, then 6% of 1.5% (1.5 x 0.06 = 0.09%) requires the pellet to be fed at 0.09 % of body weight or 0.09 lb per 100 lb of body weight. If the feeding directions suggest feeding at 0.3 lb per 100 lb of body weight, then this product will be more than adequate in supplying zinc. The same calculation for copper would show that 0.27 lb per 100 lb of body weight (1.5 x 0.18 = 0.27) must be fed. In comparing results, the pellet provides far more zinc at suggested feeding rate and just enough copper. This calculation can be completed for any or all nutrients to assess adequacy of a supplement.

Feeding Trial. Once you have determined whether or not a given supplement will deliver the appropriate amount of nutrients and is balanced with your forage, you need to determine if your animals will consume the product at an appropriate level of intake. Remember, nutrient delivery on a daily basis is the product of supplement nutrient concentration multiplied by intake amount.

Expected intake and nutrient delivery is a confounding problem with feeding supplements. Most products are designed to be fed similar to other domestic species. For pellet products, most intake expectations are fairly reasonable at 0.3 to 0.5 lb/day. However, others expect more than 1 lb/day intake, which would be nearly 40% of the diet as supplement. Many people would not feed that much and certainly not to overweight animals. If intake of these products is less than recommended, then overall nutrient intake will be lower; possibly insufficient to meet needs. This concern is a more critical issue for mineral products. The expected intake of most of these products is 0.5 oz/day up to 2 oz/day. Practical feeding experience suggests, at best, free-choice salt-based mineral intake of 0.25 - 0.33 oz/day. If this is what you observe with your animals, then the calculated nutrient amounts based on feeding recommendations need to be reduced by 1/4 or 1/3 to account for the lower intake. This opens the door for even more potential problems with inadequate nutrient intake using these products.

Figure 1. Nutritional evaluation of supplements using a Pearson square. Box center (A) contains desired nutrient content of diet. Left side of box (B) has nutrient content of two different feeds to be blended together to meet requirement. Values on right side of box (C) represent differences across diagonal lines (absolute values). These values are summed (D) and percent contribution for each feed calculated. In the example, the diet would need to be 94% or 82% grass hay and 6% or 18% pellet based on calculations to meet zinc and copper requirements, respectively.



Supplement Comparisons

In recognizing nutrient variability in forages and addressing consumer demand, feed manufacturers in North America have produced a variety of supplements for llamas and alpacas. From feed tag data, it can be seen there is tremendous range in nutrient content across products. Part of this variation can be attributed to differences in expected intake of the pellet or mineral. To better compare supplements, amounts of each nutrient were determined for a defined animal [Van Saun, 2003]. Free-choice mineral intake calculations were based on the expected intake taken from the feed tag. In simply comparing nutrient amounts delivered to suggested nutrient requirements, mean nutrient amounts across products meet or exceed needs. However, there is still much range in nutrient delivery; in some cases more than 20-fold differences. As already addressed, specific nutrient requirements of camelids have not been defined. As a result, most commercial camelid supplements mimic current products for sheep, cattle, horses or some variation on the theme. Relative to copper, supplements formulated for horses or cattle may contain excessive amounts and potentially increase risk of toxicity. Sheep products typically contain less copper. Nutrient content of many supplements does not account for variation in forage nutrient content, let alone whether grass or legume forages are being fed. There is much room for improvement in the formulation of llama and alpaca supplements, but first we need solid research-based data to better define daily requirements.

Summary

To maintain high expected productivity and health in your animals, supplement feeding over-and-above your forage program will be necessary. The question then becomes: "Which supplement best fits my needs?" Unfortunately there is no one simple answer. Supplements must be balanced to the prevailing forage feeding program. Ultimately, one needs to match nutrient delivery (intake x content) from forage and supplement to defined animal requirement. However, there are no currently accepted guidelines for nutrient requirements in camelids. As a result, owners are left in a state of confusion as to whether or not their supplement is adequate. Information presented can be helpful in making a more informed decision in feeding supplements. Owners are encouraged to work with their attending veterinarians in monitoring animal performance and nutritional status as a method to determine adequacy of their supplement feeding program.

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