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Small Ruminant Series

Minerals

by Dr. Rick Machen
Associate Professor & Extension Livestock Specialist
Texas Agricultural Extension Service, Uvalde

As mentioned in previous articles, the nutrient requirements of goats are not well defined - certainly not as well defined as those for beef and dairy cattle, sheep, swine or poultry. Much of the research with goats has involved dairy goats in confinement-fed conditions. Very little work has been done with free grazing goats.

To determine nutrient requirements, research scientists must create an artificial environment wherein goats are deficient in the particular nutrient of interest. Then, under very controlled conditions, the nutrient of interest is added to the diet in increments until growth, lactation or the physiological response per additional increment of nutrient is negligible. To add further complication, mineral requirements are dependent upon age, sex, stage and level of production and can vary across breeds within a species of livestock.

Research projects of this type are quite expensive and time consuming. Consequently, many of the mineral specifications used in the development of goats feeds are extrapolated from other species or are the result of practical experience.

Factors Affecting Mineral Content of Forages

Plant content of mineral elements is dependent upon the interaction of a number of factors including soil, plant species, stage of maturity, yield, pasture management and climate. Most naturally occurring mineral deficiencies in herbivores are associated with specific regions and are directly related to soil characteristics.

Young and alkaline geological formations are tend to be more abundant in most trace elements than the older, more acid, coarse, sandy formations. Significant leaching and weathering of soils in tropical regions, under conditions of heavy rainfall and high temperature, accentuate mineral deficiencies.

It is generally accepted that forbs (weeds) and legumes are richer in a number of minerals than are grasses. For example, legumes contain over twice as much calcium as grasses and are more than adequate to meet animal requirements.

As plants mature, mineral content declines due to the natural dilution processes and

translocation of nutrients to the root system. Micromineral concentration of forages across growing seasons is generally less variable than macromineral concentrations.

Mineral Nutrition

Minerals are divided into categories relative to the amount thought to be required in the diet of ruminants. The seven major essential minerals (in addition to carbon, hydrogen, oxygen and nitrogen; *refer back to article on protein*) and nine minor essential minerals are listed in Table 1. Macromineral requirements are usually expressed as a percent of the diet while micromineral requirements are typically quoted in parts per million (ppm) of the diet.

Other minerals which are possibly essential at very low levels include chromium, nickel, vanadium, silicon, tin and arsenic.

Table 1. Macro- and microminerals.

Macro	Micro
Calcium	Iron
Phosphorus	Iodine
Sodium	Copper
Chlorine	Zinc
Magnesium	Molybdenum
Potassium	Manganese
Sulfur	Cobalt
	Selenium
	Fluorine

Bioavailability is a concern when considering mineral nutrition, because for most minerals, it is less than 100%. For example, if a doe is fed 4 grams of mineral X, the amount of mineral X that is digested, absorbed and available for use will be less than 4 grams. Depending upon the chemical structure, bioavailability can range from zero to over ninety percent. In general, availability is highest for sulfates, intermediate for carbonates and lowest for the oxide forms of a mineral. Using supplemental iron sources as an example: ferrous sulfate > ferrous carbonate > ferric oxide.

Bioavailability of one mineral is also influenced by the concentration of other minerals in the diet. For example, high levels of sulfur or molybdenum interfere with copper absorption. While analysis of the copper concentration in the diet may reflect a sufficient amount, because of this antagonism, an animal may actually be copper deficient.

Practical determination of animal s mineral status is often very difficult. Blood analysis is a poor indication of mineral status for many of the minerals. The body has a significant storage capability for many of the minerals (for example, the calcium in bone). Therefore, until body reserves are depleted, symptoms of deficiency may not be apparent. More involved processes like liver biopsy may be required to determine the mineral status of an animal.

Macrominerals

Following is a very brief list of some of the functions of macro- and microminerals in the body. Obviously, space does not allow a detailed description of each mineral and its numerous functions throughout the body.

Calcium (Ca)	Most abundant mineral in the body; 98% is found in the bones and teeth. Functions in blood clotting, membrane permeability, muscle contraction, nerve function, cardiac regulation and enzyme activation. Vitamin D is required for active absorption. As dietary Ca intake increases, absorption is reduced. Cereal grains (corn, oats, milo, wheat, barley) are low in Ca.
Phosphorus (P)	The most deficient mineral throughout the world. Must be supplemented to livestock grazing native forages in order to meet requirements. Eighty percent of P in the body is found in the bones and teeth. Functions with Ca in bone formation, is essential for cell growth, energy utilization, maintaining acid:base balance, is a component of DNA and is required by rumen microbes for optimal growth and activity. The greatest bang for the buck in mineral supplementation is generally associated with providing P. Oilseed meals are an excellent source of P. Palatability is low.
Potassium (K)	The third most abundant mineral in the body. Essential for the maintenance of osmotic and fluid balance in the body. Cereal grains and mature, weathered forages have low K contents. Oilseed meals and green, growing forages are an excellent source.
Magnesium (Mg)	Sixty-five to 70% is found in the skeleton. Functions in carbohydrate and fat metabolism and is a catalyst in over 300 enzyme systems. Like phosphorus, Mg is bitter and is sometimes used to limit consumption of mineral supplements.
Sodium (Na)	Usually considered with chlorine (Cl). Sodium chloride (NaCl) is salt. Both are critical electrolytes in body fluids. Sodium functions in amino acid and glucose transport and muscle contractions. Chlorine is a component in hydrochloric acid formation and activation of amylase, a starch digesting enzyme.
Sulfur (S)	Two amino acids (methionine, cysteine) and two B-vitamins (biotin, thiamin) contain S. Also functions in maintaining bone, cartilage, tendon and blood vessel integrity (contained in chondroitin). Note: Rumen microbes are capable of synthesizing all of the sulfur containing compounds from inorganic S. High S levels in the diet antagonize the use of copper and molybdenum.

Microminerals

Copper (Cu)	Copper is second only to phosphorus in severity of deficiency throughout the world. Copper is involved in hemoglobin formation, enzyme systems, nervous and immune system function. Copper interacts with iron, zinc, sulfur and molybdenum in antagonistic relationships. Sheep are very susceptible to copper poisoning as dietary Cu levels approach or exceed 20 ppm.

Iodine (I) — Primarily involved in the thyroid hormones that regulate rate of metabolism. Deficiency usually not a problem except with goitrogenic forages or feedstuffs like turnips, kale, rape, white clovers. Cottonseed and soybean meal have some goitrogenic properties. Use of iodized salt has eliminated I deficiency problems.

Iron (Fe) — Involved in cellular respiration and oxygen transport via hemoglobin. Fifty percent of the body s iron is involved in hemoglobin. Can antagonize copper and zinc availability.

Zinc (Zn) — Important in stress management, immune response, enzyme systems and protein synthesis. Second only to Cu on the list of likely micromineral deficiencies.

Selenium (Se) — Involved in the prevention of white muscle disease. The requirement for Se is very close to its toxicity level.

Manganese (Mn) — Cofactor in several enzyme systems.

Cobalt (Co) — Component of vitamin B_{12}.

Table 2. Macrominerals and their requirements.

	% of diet
Calcium	0.20 - 0.80
Phosphorus	0.20 - 0.40
Potassium	0.50 - 0.80
Magnesium	0.12 - 0.18
Sodium	0.09 - 0.18
Chlorine	-
Sulfur	0.14 - 0.26

Source: National Academy of Science, Nutrient Requirements of Goats, 1981.

Mineral Requirements

Mineral requirements for the macro- and microminerals are shown in Tables 2 and 3, respectively. Notice the requirements are presented as ranges and not absolute numbers. As previously mentioned, mineral requirements are not well defined in the scientific literature and are influenced by many factors. These tables are presented here only for reference purposes, not as standards against which to hold those who develop mineral supplements.

It is generally recommended that the dietary calcium:phosphorus ratio be at least 2:1, especially if wethers are to be fed. In addition, phosphorus levels above 0.38-0.40 do not enhance performance and appear to aggravate potential urinary calculi problems.

Mineral Supplementation

Minerals can be provided to livestock directly or indirectly. Indirect methods include fertilizers, changing soil pH, establishment of forage species known to have high content of the mineral(s) in concern and foliar sprays. Mineral fertilization is not an efficient method of increasing the intake of minerals by livestock. In general, the indirect methods of supplementation are neither cost effective nor practical.

Direct methods of supplementation include adding deficient minerals to the drinking water, oral drenching, injection, ruminal boluses, force-feeding in protein/energy feeds and free-choice supplementation.

Of these, free-choice supplementation is the most widely used method for grazing ruminants. Development of a balanced, palatable, free-choice mineral with predictable consumption by goats is difficult and requires significant practical experience.

Mineral consumption varies daily, across animals within the herd and across seasons of the year. Forage quality, dry matter content, degree of hunger and level of boredom seem to influence the amount of mineral consumed.

Commercially prepared free-choice minerals are generally developed for specific geographical areas to meet 100-125% of the average herd s requirement reared in the average environment for that region. Unfortunately, there is no average herd or environment.

Observations

If it is not broken, do not attempt to fix it! If nutrient requirements are currently being satisfied and the goat herd is performing (growth, reproduction, milk production, appearance) as expected, changes in the nutrition program are not warranted.

Balanced feeds & other supplements. Most commercially prepared goat feeds are balanced for the entire mineral profile and do not require mineral supplementation. Goat s mineral requirements can be met without feeding a mineral supplement. Mineral supplements are most often warranted when goats are grazing, especially when forage is dormant, mature and/or weathered.

The ability to include mineral/vitamin fortification and present a complete balanced package affords commercially prepared feeds a significant advantage over feeds mixed on the farm.

Salt - both White and Yellow. Despite a popular opinion within the livestock industry, neither of these qualify as a mineral supplement. In most cases, the sodium and chlorine requirements are met without feeding salt.

Animals, like humans, like the taste of salt. Salt is sometimes used to limit the consumption of free-choice oilseed meal and/or ground cereal grain supplements. If a mineral supplement is offered, do not offer free-choice salt.

Cost vs. consumption. On a $/50 lb sack basis, mineral supplements are expensive when compared to other feeds or supplements. Remember, daily consumption should be relatively low. A rule of thumb for daily mineral consumption by mature goats on pasture is 0.75 -1.0 oz or 25-30 g per day. Consumption may be excessive immediately after introduction to mineral, but will generally level off after 10-14 days. Mineral must be consumed if it is to benefit the goats.

Soil sulfur. Areas near coal-fired power plants and pastures with a long history of fertilization with sulfate fertilizers may have soils with unusually high sulfur content. As previously mentioned, excessive dietary sulfur can antagonize the availability of other minerals in the diet.

Table 3. Microminerals and their requirements.

	ppm
Copper	10 - 20
Zinc	20 - 33
Iron	30 - 50
Manganese	20 - 40
Iodine	0.10 - 0.80
Molybdenum	0.50 - 1.0
Cobalt	0.10 - 0.20
Selenium	0.10 - 0.20

Source: Personal experience and experimental data.

Copper content. Sheep are very susceptible to excess dietary copper. Most sheep diets are formulated to contain less than 20 ppm copper. Goats are much more tolerant of copper than sheep. Consequently, many commercially prepared goat feeds are formulated to contain 25-30+ ppm copper. Do not offer goat feeds to lambs unless the copper content is well understood.

If you have questions concerning mineral nutrition for your goats, consult a knowledgeable professional nutritionist. Your commercial feed manufacturer or an Extension professional can provide valuable assistance.