

MINERAL NUTRITION OF BEEF CATTLE



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INTRODUCTION

The mineral status of the brood-cow herd affects reproduction, growth, milk production and health. All of these can affect profitability, yet the cost of improving mineral status is low compared to production returns.

This publication's focus is on "mineral optimization," which emphasizes the dynamics of minerals in living tissue. Cattle have evolved an elegant system for storing and retrieving minerals from various body stores as they are needed. The success of this system depends upon reliable replenishment from dietary sources.

Body tissues have constantly changing mineral demands. No producer can precisely match the varying needs of each animal by manipulating the mineral supplement. Instead, the strategy is to provide supplemental mineral resources to keep tissue stores "optimally mineralized" so that ever-changing biological needs are met. Unfortunately, there is not a single, simple "recipe" or product that covers all situations.

It is not a goal of this publication to provide an exhaustive, systematic compendium of mineral information. Such publications exist and relevant information has been extracted to develop this "applied" publication.

Before examining cow-calf mineralization in detail, consider these basics:

- Mineral deficiency is more common than once thought, but it is no more common than protein or energy deficiency. All aspects of a good nutrition program must be kept in mind while mineral nutrition is improved by following guidelines in this publication.

- Consumption is important! This seems obvious, but is critical and must be emphasized. Cow-calf herds are generally provided minerals "free-choice." Cows may or may not "choose" to consume adequate amounts of mineral. This is why mineral consumption must be monitored, especially when a new mineral is introduced, or during critical periods (such as when magnesium levels are increased in an attempt to prevent grass tetany).
- Genetics may affect mineral needs. Genetic selection for improved milk production or increased gain increases nutritional mineral demands for both cows and calves. There are also breed effects. Recent research, for example, has indicated that continental breeds require higher dietary levels of copper and selenium.
- Mineral deficiency symptoms may be the result of an imbalance. Symptoms of copper deficiency (rough hair coat, unthrifty appearance) are occasionally observed in spite of copper inclusion in supplements. This is possible because sulfur and/or iron are often in excess in either feed or water (also molybdenum, but this is not as likely in Tennessee).

MEETING THE MINERAL NEEDS OF THE BEEF ANIMAL

Beef cattle need minerals to remain productive and healthy. Some minerals are needed in greater quantities than others. A listing of needed minerals, their functions and sources is presented in Table 1.

Table 1. Minerals and Their Functions in the Body.

Mineral	Most Significant Known Functions in Body	Source
Macro Minerals (required in larger amounts)		
Calcium	Bone & teeth formation, nerve & muscle function	Forages
Phosphorus	Reproduction, health of bones and teeth	Grains
Magnesium	Growth, reproduction, metabolic functions	Mineral supplement
Potassium	Metabolic functions	Forages
Sulfur	Metabolic functions, amino acid formation in rumen	Forages & grains
Micro Minerals (required in smaller amounts)		
Chromium	Immune response, glucose tolerance factor	Cereal grains
Cobalt	Component of Vitamin B12	Legumes
Copper	Hemoglobin formation, tissue metabolism	Forages & grains
Iodine	Production of thyroid hormones, energy metabolism	Forages
Manganese	Reproduction enzyme formation	Forages
Molybdenum	Enzyme activity	Forages
Selenium	Antioxidant, glutathione peroxidase	Grains & forages
Zinc	Enzyme activity	Legumes

MAJOR MINERALS

The major minerals (macro-minerals) are those minerals needed in the largest quantity in cattle diets. The requirements for these minerals are typically presented as percentages. The major minerals are usually considered to be salt (sodium-chloride), calcium, phosphorus, magnesium, sulfur and potassium. Table 2 shows these minerals, the approximate requirements under typical conditions and the maximum tolerable concentrations.

Table 2. Macro-Mineral Requirements and Maximum Tolerable Concentrations.

Mineral	Unit	Requirements			Maximum Tolerable Concentration
		Growing and Finishing Cattle ¹	Cows (1200 lb.)		
			Gestating	Early Lactation	
Calcium	%	0.36	0.15	0.25	N.A.
Chlorine	%	N.A.	N.A.	N.A.	N.A.
Magnesium	%	0.10	0.12	0.20	0.40
Phosphorus	%	0.19	0.12	0.17	N.A.
Potassium	%	0.60	0.60	0.70	3.00
Sodium	%	0.06 - 0.08	0.06 - 0.08	0.10	N.A.
Sulfur	%	0.15	0.15	0.15	0.40

¹Calcium and phosphorus requirements in this table are based on 605-lb. steer or heifer (mature weight = 1100 lb.) gaining 1.88 lb. per day. Source: Nutrient Requirements of Beef Cattle. 1996. Washington, D.C. National Research Council

MICRO-MINERALS

Micro-minerals are those required in smaller quantities than macro-minerals. These are sometimes called “trace” minerals. Indeed, such small amounts are required that it has often proven difficult for scientists to establish the proper levels for supplementing these minerals, or whether there is a need for supplementation. The trace minerals believed to be required for normal functions are shown in Table 3.

Table 3. Micro-Mineral Requirements and Maximum Tolerable Concentrations.

Mineral	Unit	Requirements			Maximum Tolerable Concentration
		Growing and Finishing Cattle ¹	Cows (1200 lb.)		
			Gestating	Early Lactation	
Chromium	mg/kg ¹	-----	-----	-----	1,000.00
Cobalt	mg/kg	0.10	0.10	0.10	10.00
Copper	mg/kg	10.00	10.00	10.00	100.00
Iodine	mg/kg	0.50	0.50	0.50	50.00
Iron	mg/kg	50.00	50.00	50.00	1,000.00
Manganese	mg/kg	20.00	40.00	40.00	1,000.00
Molybdenum	mg/kg	-----	-----	-----	5.00
Nickel	mg/kg	-----	-----	-----	50.00
Selenium	mg/kg	0.10	0.10	0.10	2.00
Selenium	mg/kg	0.10	0.10	0.10	2.00
Zinc	mg/kg	30.00	30.00	30.00	500.00

¹Mg/kg is the same as parts per million (ppm). Micro-minerals are usually expressed in parts per million (ppm) or mg/kg (10 ppm of a mineral equals 10 mg/kg of ration dry matter). Source: Nutrient Requirements of Beef Cattle. 1996. Washington, D.C. National Research Council

In recent years there has been increased emphasis on trace mineral supplementation because:

1. Requirements for micro-minerals are simply more accurately defined today. More is known about their essential functions. Production losses resulting from marginal deficiencies often existed but were not recognized.
2. The genetic potential for performance and productivity of cattle has increased requirements. When cattle are pushed to perform to a higher genetic potential, mineral demands increase. If these demands are not met, performance is reduced.
3. In cattle and sheep, breed can greatly influence copper requirements and susceptibility to toxicity. For years it has been well established that breeds of sheep vary in their susceptibility to copper toxicity and requirements for copper. Recent research indicates Simmental and Charolais cattle require more copper in their diet than Angus (Herd, 1997). Field experiences suggest that Simmental, Maine Anjou, Limousin and Charolais cattle all benefit from 1.5 times the copper intake normally defined for traditional breeds. On the other hand, it appears that Jersey cattle are much more susceptible to copper toxicity (MTC is possibly as low as 40 PPM of the diet compared to the normally accepted 100 PPM) than Holsteins. Brahman cattle may be more susceptible to copper toxicity than other beef breeds. Thus, producers must carefully evaluate the needs of their particular cattle. Genetic differences quite likely exist within all breeds.
4. In situations where yields of crops have been increased with nitrogen, phosphorus and potash fertilizers without accompanied repletion of trace elements, the content of many of the trace elements in feedstuffs has decreased over time. The decrease is especially true for shallow-rooted crops.
5. Liming, fertilization practices and/or industrial pollution may be altering the composition or proportion of minerals in forages in certain areas.
6. Dietary copper requirements are affected by antagonists such as molybdenum, sulfur, iron and other elements that decrease the bioavailability of the copper in the sample (Table 4a). This results in a requirement for a higher concentration of copper. Concentrations considered to be highly antagonistic have been established for some elements (i.e., iron, molybdenum, sulfur, zinc). However, when more than one antagonist is present in a diet, there appears to be an additive effect in reducing the bioavailability of copper. Interpreting these complex relationships is extremely difficult based on forage analyses. Thus, when antagonists are present at relatively high levels or a combination of antagonists are present, one of the best ways of monitoring animal copper status is not through analysis of forage samples, but through analysis of tissue samples such as liver biopsies.

ASSESSING AND IMPROVING THE MINERAL STATUS OF TENNESSEE FORAGES AND BEEF CATTLE

Beef producers in Tennessee have worked closely with the University of Tennessee Extension faculty and staff in assessing the mineral status of their forages and cattle herds. The motivation for this has been widespread reports of problems, coupled with a coordinated effort to improve the means by which these problems can be solved.

These problems have sometimes been related to such things as grass tetany due to magnesium deficiency (and possible excess potassium), but are also related to deficiencies and imbalances of copper, sulfur, zinc and possibly selenium and other minerals.

The symptoms reported by cattle producers include rough, discolored hair coats (with cows and calves slow to shed winter hair coats). Symptoms also include decreased breeding efficiency (slow breeders, depressed heat cycles), bone and hoof problems and depressed immune system function (less resistance to diseases ranging from scours in

young calves to shipping fever in weaned calves and possibly even decreased resistance to parasites).

Forages provide the majority of the nutrients needed by beef animals in Tennessee. Table 4a reveals the levels at which forage minerals are considered adequate, marginally deficient or deficient. This table is more detailed than Table 3, and is designed to be more helpful in understanding the forage-related deficiencies and imbalances such as those presented in Table 5.

Table 4a. Classification of Trace Elements in Forage Relative to Their Abilities to Meet Dietary Requirements.

Trace Minerals	Deficient	Marginally Deficient	Adequate	MTC*
Aluminum(ppm)	--	--	--.....	1000
Copper (ppm)	below 4	4-9.9	\$10.....	100
Manganese (ppm)	below 20	20-39.9	\$ 40.....	1000
Zinc (ppm)	below 20	20-29.9	\$ 30.....	500
Selenium (ppb)	below 100	100-199.9	200.....	2000
Copper:Mo Ratio	below 4.0:1	4.0-4.5:1	>4.5-5:1.....	--

*Maximum Tolerable Concentration

In many cases, it is important to understand when levels are too high, because this creates imbalances where one mineral may interfere with the function of another mineral or several minerals. This is often referred to as an “antagonistic” level.

Table 4b. Minerals Typically Antagonistic to Copper.

Copper Antagonist	Deficient	Ideal	Antagonistic Level**		MTC*
			Marginal	High	
Iron (ppm)	below 50	50-200	>200-400	>400	1000
Molybdenum (ppm)	--	below 1	1-3	above 3	5
Sulfur (% DM)	below. 10	.15-.20	>.20-.30	>.30	.40

* Maximum Tolerable Concentration
 **Levels above these can potentially adversely affect copper availability. (Mortimer, et al., 1999)

The 2001-2004 Tennessee Forage Mineral Survey

In an effort to determine the extent of this mineral imbalance and/or deficiency problem, Extension agents collected 1021 forage samples from across the state during the spring (May) and fall (August/September). The means and standard errors for year and season are listed in Table 5.

Results of the Tennessee Forage Mineral Survey include:

- A. Copper (Cu) levels were in the deficient range. The desired level of copper in forages is 10 ppm. It was not a surprise that average copper concentrations were low (see Table 5), but it was revealing that levels were lower in late summer / fall. The Copper (Cu) was at least marginally deficient in 92.4 percent of the samples. This is consistent with work from Virginia Tech (Saker, et al., 1998) showing that the endophyte fungus (*Neotyphodium coenophialum*) commonly found in Kentucky 31 tall fescue depresses copper availability.

- B. Sulfur (S) levels were high. Sulfur limits copper availability to cattle. Sulfur concentrations in forage were variable, but were consistently within the range considered to be antagonistic to copper availability (levels above 0.25 percent are considered antagonistic). Sulfur (S) was considered at least marginally antagonistic to copper in 89.3 percent of the samples.
- C. Magnesium (Mg) levels were low in the spring, while Potassium (K) levels were surprisingly high. Low Mg was not surprising, as this has long been known as the single most important risk factor in grass tetany. More revealing was the high concentration of potassium, which is known to interfere with magnesium absorption. Approximately one-quarter of the potassium levels were above 3 percent, which is considered high enough to increase the risk of grass tetany. In the spring (when grass tetany is most likely to occur) almost one-third of the samples were high in K.
- D. Zinc (Zn) was marginally low, with Phosphorus (P), Calcium (Ca) and Manganese (Mn) within acceptable levels. Zinc was at least marginally deficient in 83.1 percent of the forage samples. Phosphorus was not as low as might have been expected. This may allow mineral mixtures to be formulated with slightly lower levels of this mineral. Calcium levels were generally not at levels to be considered problematic, but mineral supplements should continue to be formulated with calcium higher than phosphorus. The calcium: phosphorus ratio should be in the range of 2:1. Manganese was not generally deficient.

Table 5. Forage Mineral Concentrations by Year and Season.

	Year				Season	
	2001	2002	2003	2004	Spring	Fall
Calcium, %	0.53 ^A	0.53 ^A	0.51 ^A	0.57 ^A	0.49 ^B	0.57 ^A
Phosphorus, %	0.36 ^A	0.42 ^A	0.35 ^A	0.34 ^A	0.35 ^A	0.39 ^A
Sodium, %	0.01 ^B	0.01 ^A	0.01 ^{AB}	0.01 ^B	0.01 ^A	0.01 ^B
Magnesium, %	0.26 ^A	0.27 ^A	0.26 ^A	0.25 ^{AB}	0.23 ^B	0.29 ^A
Potassium, %	2.63 ^A	2.52 ^B	2.56 ^{AB}	2.54 ^{AB}	2.65 ^A	2.46 ^B
Sulfur, %	0.28 ^{AB}	0.27 ^B	0.28 ^A	.28 ^{AB}	0.26 ^B	0.29 ^A
Manganese, ppm	106.24 ^B	110.41 ^B	131.32 ^A	113.45 ^{AB}	113.27 ^B	117.44 ^A
Copper, ppm	7.56 ^A	5.06 ^C	6.90 ^B	7.99 ^A	6.99 ^A	6.76 ^A
Zinc, ppm	24.92 ^B	21.47 ^C	28.05 ^A	22.04 ^{BC}	22.75 ^B	25.50 ^A
^{A,B,C} Row means within year and season not sharing superscripts are significantly different at $P < 0.05$.						

Serum Mineral Levels

Blood samples were taken from approximately 20 cowherds and a portion of the bulls consigned to the University of Tennessee Central Bull Test Station. Table 6 lists the number of samples, means and ranges for serum copper and selenium samples taken in Tennessee in 2002. Table 7 lists the ranges used to characterize the serum copper and selenium levels. Serum levels confirm the existence of problems and allow individual producers to assess their situation.

Table 6. Serum Mineral Levels of Selected Tennessee Cattle in 2002.

ppm	Number	Mean	High	Low
Copper	256	0.64	1.40	0.32
Selenium	162	0.108	1.009	0.024

Table 7. Ranges Used to Characterize Serum Mineral Levels.

ppm	Deficient	Marginally Deficient	Adequate
Copper	< 0.55	0.56 - 0.79	0.8 - 1.5
Selenium	0.002 - 0.025	0.026 - 0.079	0.08 - 0.3

Blood testing is not necessarily encouraged unless problems are suspected. If problems exist or are suspected, blood testing may be helpful in assessing the situation. However, results of blood tests should be considered only in the context of an evaluation of symptoms and forage analyses. Most laboratories report blood test results with benchmark levels that allow interpretation of results. In general, liver analysis is considered a better indicator of copper status than blood serum, but many producers are reluctant to go to the extent of asking their veterinarian to obtain liver samples. Mineral deficiency and imbalance problems can usually be diagnosed and solved without the need for liver testing.

Addressing Mineral Problems in the Herd

The imbalances revealed in the 2001-2004 Tennessee Forage Mineral Survey are consistent with symptoms reported in Tennessee. Cattle producers are encouraged to examine their current mineral programs, but should keep the following in mind:

1. All problems are not due to minerals. It is still important to strive to improve forage quality and to insure that cows receive adequate energy and protein to match their nutritional demands during pregnancy, nursing, rebreeding and weaning periods.
2. Monitor mineral consumption. The best mineral formula in the world won't work if the cows don't eat it. There will be variability in mineral consumption during the year, but it is critical that average consumption be near the level for which the mineral was designed (usually provided on the label or by mineral dealer).
3. Work with your mineral dealers. Ask questions. The data from the Tennessee Forage Mineral Survey has been shared with all mineral dealers who sell significant amounts of mineral supplements in Tennessee. Most have either reformulated based on this data, or have addressed the issues by changing the availability of product lines appropriate to Tennessee. Avoid making hasty decisions based on incomplete information. Mineral nutrition is not an easy topic, and problems may require careful attention and some effort to solve. In certain cases, the beef producer may need a specialized supplement that may have to be prepared on a custom basis. While this may not be an attractive alternative to smaller producers, owners of larger herds may find the per-unit discount of bulk purchasing to be advantageous.

4. It is possible to have too much of a good thing. Most breeds of beef cattle, for example, are relatively tolerant of the levels of copper commonly available, but Jersey cattle and sheep are susceptible to copper toxicity (it can be lethal to these animals). Selenium toxicity is possible, but unlikely due to legal limitations on levels of inclusion in mineral supplements. As mentioned in the text above, potassium levels were higher than expected in the forages. This should be fair warning to beef producers not to be adding potassium to pastures unless soil tests call for it. Mineral manufacturers are aware that K levels are often high in Tennessee forages and are formulating mineral supplements accordingly.
5. Some cattle herds may have higher mineral requirements. Many producers have made substantial genetic improvements in their herds. Genetically superior cattle, with more potential for milk production and calf growth, may have increased mineral requirements (also protein and energy). Certain breeds, such as Simmental, Charolais and Limousin, have been shown in research to have higher copper requirements.
6. Imbalances can be corrected by supplementation. If sulfur levels in the diet are high, additional copper in the supplement can correct the problem. There is evidence, however, that the form of copper in the mineral supplement is almost as important as the level. Copper oxide, for example, is a poor source of copper and should be avoided in supplements. Copper sulfate and copper chloride are commonly used inorganic sources, the latter having the advantage of being devoid of sulfur, which may be a problem in sulfur imbalance situations. Organic copper sources (such as chelates) are the most biologically available, and may have an important role in correcting copper: sulfur imbalance problems. Chelates are more expensive, and there is evidence they are most efficiently used in combination with inorganic sources of copper.
7. Selenium could be a problem, if not properly supplemented. Selenium analysis is difficult, so only 30 samples were analyzed for selenium in the Forage Mineral Survey. More than 93 percent of the samples were in the deficient range. Other studies have shown that selenium deficiency can be a problem in this region. As with copper, sulfur is antagonistic to selenium, so deficiencies in selenium might be expected. Symptoms of selenium deficiency range from increased incidence of retained placenta (failure to pass afterbirth) to compromised immune function (more sickness, especially under stress). There are legal limitations to the level of selenium that can be added. Most companies that make and sell minerals in Tennessee have products that incorporate selenium at or near the legal limit. In general, research has shown that organic forms of selenium (chelated or yeast-cultured) are more biologically available. Since FDA limits the amount that can be added to supplements, the higher availability of organic forms makes them attractive as a potential source of selenium, particularly if Se deficiency situations are suspected. However, the additional expense of organic sources may limit routine incorporation in mineral mixtures. Combinations of inorganic and organic may be used and may be advantageous. Recent changes in FDA clearances on selenium yeast may result in wider use of products with that form of selenium. (Dr. Chris Richards, UT Animal Science Department assistant professor, has been instrumental in assisting with selenium analysis and advice in this area).
8. If it ain't broke, don't fix it. If your calving rate is good (90 to 95 percent calf crop), your cattle have healthy coats of hair and there is little sickness, you may not need to change your mineral program. We do not encourage everyone to change; we simply hope this information will give you a basis for examining your herd's production efficiency and your mineral supplementation strategy.

EVALUATING THE COW HERD FOR MINERAL-RELATED PROBLEMS

If production problems exist in a herd, it is necessary to carefully and logically assess the problem before the best solution can be found. Making random changes based on incomplete data and insufficient advice may cause more harm than benefit. Following are some suggestions for assessing the situation and making logical changes:

- Carefully evaluate symptoms – Eliminate obvious alternative causes such as simple malnourishment, toxins or infectious disease before deciding that minerals are the basis for the problem.
- Use laboratory analyses – Both commercial and university laboratories are available to assist in diagnosing mineral problems. Typically, the feed or forage resource being fed is analyzed for all minerals that could be related to the problem (deficiency or excess). In some cases, the water supply is tested; however, certain minerals may volatilize easily from water, so assessment results may be misleading. It is often recommended that blood samples be taken for serum assay, but results of blood work should be assessed with care because many factors can affect blood mineral levels. Soil mineral profiles are similarly of limited value in most cases.
- Assess possible interference factors – Any source of pollution or unusual contamination should be considered. Is there any factor that could suppress the biological availability of certain minerals?
- Assess the existing mineral program – Observe the labels of minerals being fed. Are there either unusual amounts or proportions? Read the ingredient list. Are sources of ingredients of questionable biological availability? Is the manufacturer known to be reputable? Contact the manufacturer if there are questions. Reputable manufacturers will have representatives who are glad to assist in working through problems.
- Use available expertise – No single person knows everything, but many experts are available who can assist in working through problems. Most farmers start with the county Extension agent, their feed dealer and/or the local veterinarian. In most cases, these people can be helpful with mineral questions. Extension specialists are available if additional expertise is needed. These specialists often have more in-depth experience and training, as well as access to additional contacts around the country who can be called into difficult situations. The University of Tennessee College of Veterinary Medicine is another source of information on mineral-based questions, including situations in which symptoms indicate unusual pathology or toxicity. Also, don't forget the Internet. This resource is becoming more and more useful (but beware that the Internet may contain false or misleading information – exercise due caution).
- Don't over-react – Sometimes doing nothing is better than doing something that makes the situation worse. For example, selenium is often blamed for a variety of problems. It may or may not be implicated in a given situation, but it is possible to over-correct and add too much selenium. Selenium toxicity, while rare in Tennessee, is possible, especially if provided to animals by multiple routes (it can be fed, injected or given via bolus, but giving all these ways could be too much).

What about Home-mixing Mineral Supplements?

Commercially prepared mineral supplements are more widely used than home-mixtures. Recipes are available for home mixtures, but we no longer provide these recipes for the reasons listed below:

- Companies purchase ingredients in large amounts to decrease cost. Individual producers, particularly those with small herds, may find it expensive to purchase sufficient quantities of ingredients to mix a “complete” mineral at a reasonable cost. The cost of labor in preparing home mixtures should be considered.
- Companies mix often and in large quantities, so mistakes are less likely. In addition, reputable companies have quality-control procedures to additionally minimize the risk of error. Conversely, individual producers often do not have the equipment needed to prepare a safe, effective mixture.
- Most home-mixed recipes solve the problem of numerous ingredients simply by adding trace-mineralized salt to dicalcium phosphate, monocalcium phosphate or limestone. This procedure may have worked in the past with lower-producing cattle, but may not be as reliable as using a commercially prepared mixture that has been formulated by experts who understand the complex interactions within mineral mixtures.

If a producer wants a mineral supplement that “fits” his or her situation, a more suitable alternative is to have a commercial company develop a “custom” mixture. This approach may require the purchase of one to three tons of mineral at a time, so will not be as attractive to smaller producers. Mineral supplements are relatively stable, but it is generally recommended that no more than three to four months supply be purchased at any one time.

If possible, work with a nutritionist to come up with a formulation that works with your cattle on your farm. The recommendations are included as a basis for producers who prefer the “custom-mixed” approach. Ideally, these recommendations are best if based on forage mineral tests, possibly on blood tests of the animals involved, and a water analysis.

Hair Coat Is an Indicator of Health

The health of the hair coat of animals is an indicator of their general health. Cattle with healthy hair coats are more likely to grow and perform to their genetic potential, while cattle with dull, off-colored hair are likely to be undergoing prolonged nutritional deficiencies or imbalances or to be experiencing some level of poor health.

Take care when evaluating hair coats, because hair has a different look at different times of the year. For example, in the fall, all cattle in Tennessee should have grown a new winter coat. This hair should be relatively long (as appropriate for the breed), healthy in appearance and the correct color (for example, black cattle hair coats should be black, red cattle should be red and white cattle should be creamy to white). In the late winter, the hair coats will naturally be a little duller as the natural shedding process begins. By spring (April / May) the hair coat should have been shed, leaving a slicked off appearance. If off-colored, dead hair remains into the summer, there is likely to be some type of nutritionally based health problem, often related to mineral deficiency or imbalance.

Certain mineral deficiencies (such as copper) have long been known to contribute to a poor hair coat health. Another important causative factor of off-colored hair coats in the spring and summer is tall fescue toxicosis due to the endophyte fungus, *N. coenophialum*. Recent evidence suggests the effects of this fungus may be associated with copper deficiency (Saker, et al., 1998).

The Hair Coat Scoring System may be useful in assessing mineral deficiencies and/or imbalances by helping beef cattle producers objectively evaluate the hair coats of their beef cattle (Table 8).

Table 8. The Hair Coat Scoring System.

Score	Description
1	No detectable problem; healthy coat appearance; appropriate to season
2	Slight indications of off-color, in limited amount; possibly over shoulders or around flank
3	Definite off-color, dull hair, but less than 1/3 of body; slightly slow to shed
4	Enough dead hair to cover significant percent (>50 percent) of body; slow shedding
5	Hair clearly dead in appearance; brittle; cattle not shedding normally in spring

Producers are cautioned to avoid over-interpreting the results of hair scoring. For example, having a few head that are slow to slough their winter coats in a productive herd with no other symptoms may be acceptable and no cause for changing anything.

UTILIZING FORAGE PRODUCTION TECHNIQUES TO REDUCE MINERAL PROBLEMS

The most efficient way to deal with mineral deficiencies is to feed the needed mineral directly to livestock. However, since the mineral problems in cattle are due to mineral imbalances in their diet, one place to begin to solve the problem in the herd is with the forage. Several simple steps will improve the mineral content of the forage as well as increase yield.

Reasons for Mineral Imbalances in Forage Crops

Forage crops remove minerals from the soil in varying amounts. In addition, various plant parts will have different levels. For instance, grass leaves tend to be high in calcium and low in phosphorous, while grass seedheads tend to be just the opposite, low in calcium and high in phosphorous. Because plants get these nutrients from the soil through their roots, low soil levels or poor mineral availability can limit forage mineral content. If a grass is growing rapidly, certain minerals may not be absorbed fast enough to keep leaf mineral levels adequate, as is the case with magnesium in the early spring.

Steps to Improve the Mineral Content of Forages

1. Apply fertilizer according to soil test levels. Maintaining appropriate soil nutrient levels is key for forage production. High potassium levels within forages can interfere with the ability of cattle to absorb and utilize magnesium, resulting in grass tetany. If potash (potassium) fertilizer is applied when not needed, the potassium level within the plant will increase without increasing yield. It is often more convenient to apply something like 19-19-19, but without a soil test there is no way to know how much potash and phosphate need to be applied. Generically

applying fertilizer can lead to soil mineral contents that are out of balance, resulting in potential problems in the animals. Soil testing every 2-3 years can help prevent this problem. If your herd happens to be experiencing an unusual level of grass tetany, consider both soil and plant tissue analysis. If potassium levels are high, do not add K until levels decrease, harvest the field as a hay crop (if possible) to remove as much potash as possible from the soil, and soil test each year until the level is reduced.

2. Maintain soil pH close to neutral. In the Southeast, soils tend to naturally be acidic. Over time, soils will slowly drop in pH. If nitrogen fertilizer is applied, the pH decrease can be more dramatic. As pH decreases, some minerals become less available in the soil, while others become more available. The minerals considered to be “good” (potassium, phosphorous, magnesium) are more available for absorption by plants when pH is between 6.0 and 6.5. The minerals that inhibit root and plant growth (aluminum and manganese) are tied to the soil particles at this pH. The result is a forage crop that is as healthy as possible, with actively growing roots that can take up the nutrients are available in the soil.

As pH drops below 6.0, the good minerals and the bad minerals begin to exchange places in the soil. The minerals that inhibit root growth are released from the soil particles into the soil solution, while the nutrients positive for plant growth are taken out of the soil solution and tied up on the soil particles. This hurts on two accounts. First, less of the nutrients needed for plant growth are available. Second, root growth is inhibited, which limits the plants ability to take up available nutrients. So not only is yield decreased, but the mineral content of the forage is decreased. All of this can be eliminated with adequate lime to maintain pH.

Should Micro-nutrients Be Applied to Forages to Eliminate Cattle Deficiencies?

Since the problem of mineral deficiencies in the diet of cattle start in the forage, the idea of fertilizing with micro-nutrients to increase forage content has been considered. For instance, can magnesium be applied to forage in spring to eliminate grass tetany? In short, adding a mineral to forage will increase the content of that mineral in the harvested forage. However, because of the inefficiency of plant uptake, and the problem of cost, the best approach, generally, is to give the needed mineral directly to the animal. Many times, the problem is not the amount of the mineral in the soil, but the ability to get this mineral into the plant. Adding more of the mineral to the soil will not improve plant uptake. With very few exceptions, if a mineral is needed by cattle, provide it directly.

PRACTICAL MINERAL SUPPLEMENTATION PROGRAMS

The amount of mineral supplementation that is needed and the proper method for including it in the ration depends on the level of minerals in the feedstuffs and the cattle production system. The following sections list some practical suggestions in setting up appropriate mineral supplementation programs for different cattle operations.

Mineral Supplementation for Cow-Calf Operations on Pasture

1. Buy or build a mineral feeder. Commercial supplement feeders are available in many types. The feeder should have a non-metal compartment for mineral storage, since minerals are corrosive to metal. They should also be designed so the contents are protected from the weather at all times, but the animal has ready access. Two compartments are occasionally useful for feeding different types of mineral supplements.
2. Mineral blocks may be used with or without shelter, but blocks often do not allow desired consumption levels. Many blocks also do not contain sufficient concentrations of macro- or micro-minerals for optimal production.
3. Mineral feeders should be checked at least twice per week. The supplement should be kept clean, fresh and as dry as possible. The best location of mineral boxes is near water, shade or in a part of the pasture where forage is abundant. Mineral feeders should be low enough so calves can reach the mineral. Move the feeder regularly to avoid excessive muddiness and loss of pasture due to salt spillage and accumulation in the soil.
4. Do not trust cattle to eat minerals if they need them and leave them if they don't. Cattle have "nutritional wisdom" relative to their need for salt and they will crave bones when phosphorus is deficient, but not necessarily phosphorus minerals. Mineral-deficient cattle will normally consume several times the recommended level for a given supplement. Allow cattle excess consumption for 10 to 14 days before taking steps to regulate intake.

If cattle are consuming excessive amounts of a mineral mixture, offer plain salt to curb consumption of the more complex mineral mixture. High levels of salt in the supplement will decrease intake. Molasses, grain, cottonseed meal, etc., at 5 to 15 percent of the supplement will encourage intake. Coating minerals with vegetable oils to reduce immediate chemical reaction on the cattle's tongue will enhance palatability. Manufacturing processes, such as prilling, will also aid palatability by reducing mineral dust.

5. If supplementing protein and/or energy, it is possible to include minerals in the supplement.
6. Minerals formulated for cows will work for replacement heifers when consumed at slightly lower levels. However, it is often better to use a mineral supplement formulated for stocker cattle where ionophore feed additives, etc., may be included.

Comment on Pricing Supplements

Do not be fooled by a mistaken concept that "the higher the concentration of minerals in a supplement, the better it is." For example, consider supplement A (cost \$500/ton, phosphorus 12 percent, copper 2000 ppm and consumption 2 ounces/cow/day) and supplement B (cost \$250/ton, phosphorus 6 percent, copper 1000 ppm and consumption 4 ounces/cow/day), to be equal. Just because supplement A contains twice as much phosphorus and copper does not make it better when the cows will eat only half as much. It is the actual amount and availability of each mineral consumed by the cow that counts, not the percentage or proportion of mineral in the supplement.

To determine supplemental mineral consumption, look at both the supplement intake and the concentration of mineral in the supplement. A reasonable minimal amount of the various minerals must be in a supplement, but making supplements too concentrated sometimes causes palatability problems, especially with minerals like magnesium and, possibly copper. Source of minerals is also important. Cut-rate minerals may not be as nutritionally available. Organic minerals are typically more nutritionally available, but are often expensive.

Free-Choice Mineral Mixtures

Free-choice mineral supplements should be formulated to supply the kinds and amounts of minerals that are deficient in rations being consumed by cattle. The palatability and mineral composition of free-choice mixtures largely determine whether cattle will eat enough of a mineral mixture to correct the deficiencies of their main diet. Table 9 contains typical element levels for mineral supplements.

Table 9. Example Mineral Supplement for Beef Cows on Fescue.¹

Element	Intake/head/day	
	2 oz.	4 oz.
Ca	10 to 20%	5 to 10%
P	7 to 10%	3.5 to 5%
Mg ²	2%	1%
S ³	1%	.5%
Mn	.1% (1000 ppm)	.05% (500 ppm)
Fe	.1% (1000 ppm)	.05% (500 ppm)
Cu ⁴	.18% (1800 ppm)	.09% (900 ppm)
Zn	.5% (5000 ppm)	.25% (2500 ppm)
Co	.002% (20 ppm)	.001% (10 ppm)
I	.004% (40 ppm)	.002% (20 ppm)
Se	.0044% (44 ppm)	.0022% (22 ppm)

¹Note: some of these levels, such as selenium, may be somewhat higher than seen on commercial preparation labels. This does not mean the commercial mixture is incorrect; but simply reflects that many formulations exist and a particular formulation can be workable in a certain area and not have this same level of minerals.)

²Increase magnesium during periods when cattle are susceptible to grass tetany.

³Sulfur is often in excess in Tennessee and may be deleted completely; except sulfur is often “accidentally” included as part of other mineral (such as Copper Sulfate).

⁴These levels of copper are “typical” but are not adequate in areas with significant “antagonistic” factors such as sulfur. In areas with significant sulfur (approaching or exceeding 0.3 to 0.4 percent sulfur), we recommend as high as 2500 to 3000 ppm copper in free-choice minerals (However, when high levels of copper are used, work with competent mineral dealers and/or nutritionists so that other adjustments are made to keep minerals in balance. Also carefully monitor consumption because high consumption plus high copper concentration could result in risk of toxicity. Avoid feeding high copper minerals to sheep or Jersey cattle.

Sodium chloride (salt) is included in free-choice mineral mixtures for two reasons. First, it supplies the sodium and chlorine needed by the animals, but it is also the ingredient that drives the cattle to consume the mixture. Adjusting the amount of salt can change consumption levels. Given that sodium levels in Tennessee forages are very low and often high, it is probably advantageous to maintain at least 20 percent sodium chloride in a free-choice mineral mixture. There is some evidence that higher levels may be needed in some situations (up to 1/3 salt).

A mixture adequate for free-choice feeding with grain rations would not be suited to forage-based programs. The mineral formulation in Table 9 is designed for forage-based situations, most common in Tennessee. The principal macro-mineral deficiency in grain is calcium, whereas phosphorus, not calcium, would be lacking in grass-legume mixtures.

Utilizing Magnesium Supplements to Prevent Grass Tetany

Magnesium – Although magnesium is a common element in nature, deficiencies and interactions with other minerals often lead to situations where supplementation is a practical necessity. Magnesium is essential to maintain normal dry matter intake and for optimal growth, reproduction and development. It is found primarily in bones and teeth, but up to 40 percent is found in the soft tissues.

Magnesium deficiency in Tennessee and surrounding states is most commonly associated with grass tetany. Grass tetany is a serious, usually fatal metabolic disease of cattle. It most commonly occurs in mature, nursing cows. Often one or more of the better cows in the herd are found dead or in serious distress. Warm, wet weather and rapid grass growth often leads to grass tetany. Late-winter and early-spring months are the most common times for grass tetany in the beef cow-calf herd, but fall tetany is certainly possible.

The best time to take preventative measures is in advance of the “danger.” The most common measure is to feed a mineral that is high in magnesium. Most feed companies sell high-magnesium mineral supplements and commercial mixtures that are acceptable.

Grass tetany prevention steps include:

- In herds with a history of grass tetany, it is recommended that cows be provided at least 1 oz. per day of magnesium oxide to yield at least 0.6 oz. of magnesium.
- Make certain the form of magnesium in your supplement is either magnesium oxide or magnesium sulfate (not magnesite or dolomitic limestone).
- In general, loose mixtures are preferred in situations where there is a history of grass tetany in the cattle herd, while blocks may be “OK” in low-risk situations where there has been little problem in the past.
- Do not stop feeding hay too soon. Keep hay available until cattle completely stop consuming it. Use the highest-quality hay available for lactating cows.
- Provide grain supplementation. A supplement containing a high percentage of cereal grains will provide the energy that cattle need to overcome energy deficits. Three to six pounds of concentrate supplement may prevent grass tetany and could help cows regain body condition necessary for successful rebreeding.
- After starting cattle on high-magnesium supplements, continue until “danger” is past. This is generally in late spring.
- Most producers use commercially prepared mixtures because the entire mineral profile is critical during the rebreeding period and commercial supplements are more likely to provide this. Often producers may prefer to mix their own. Extension agents have recipes for making home mixtures that are high in magnesium.

To prevent grass tetany, it is desirable to have magnesium intake at about 0.6 oz. per day. Part of this may come from forages (Fescue pastures typically contain 0.20 to 0.25 percent magnesium) or other feeds, but in serious tetany situations, it may be desirable to obtain most or all of this level from supplemental mineral. To assist in knowing the amount of magnesium obtained from the mineral, use the chart on page 18.

Mg% in Mix	Consumption of Mix (oz.)	Magnesium Intake (oz.)*
4	2	0.08
4	4	0.16
8	2	0.16
8	4	0.32
12	2	0.24
12	4	0.48
16	2	0.32
16	4	0.64

*This is calculated by multiplying consumption X % Mg in mix (2 oz. x 4%/100 = 0.08).

An example of how this table is used: If forage test indicates that the forage is 0.22 percent magnesium and the cow eats 22 lbs of dry matter per day, she is getting 0.77 ounces of Mg. However, research has shown that magnesium availability is only 10 to 35 percent. Assuming 25 percent availability, the cow is getting 0.19 ounces from forage, so must obtain about a half ounce of magnesium from the supplement. To do this, according to the table, she should be eating about 4 ounces per day of a mineral with 12 percent magnesium.

Comment on Sources of Minerals

There are two major classes of mineral sources: inorganic and organic.

Organic complexes have been shown to be more effectively absorbed by the animal. Organic complexes are created when trace elements are linked to a protein or an amino acid. Many studies investigating organic complexes have involved disease situations and the pharmaceutical factor of trace elements. In stress situations, or in areas where antagonistic levels of other minerals exist, the organic complexes may be beneficial compared to inorganic sources.

Organic complexes may also be safer. This is important when “higher-than-normal” levels of minerals must be added to overcome antagonists.

Even when mineral composition of feeds and forages is known, there is still a problem with the availability of these minerals to livestock. Minerals are variable in availability. Most minerals in feedstuffs are in an organic form, but being “organic” does not always mean they are available. For example, phosphorus in plants is usually combined with the organic compound, phytin. Phytin phosphorus is not well used by single-stomach animals. Ruminants can use phytin phosphorus more efficiently than single-stomach animals.

As a general rule, the bioavailability of inorganic mineral sources follows this order: sulfates = chlorides > carbonates > oxides. Research indicates copper oxide is a very poor source of copper for use in mineral supplements. However, because of a much longer retention time in the rumen / reticulum for absorption, copper oxide needle boluses are effective copper sources. Work is currently under way to evaluate the role of including additional minerals with copper in formulations for use in boluses.

Iron oxide, which is used as a red food coloring agent for minerals, is poorly available but may still act as an antagonist to copper absorption.

At this time, we are still learning the role of organic forms of minerals (enriched yeast, proteinates, complexes and chelates). Evidence is accumulating that specific mineral forms may be absorbed by different pathways and transported and metabolized by different routes. This means that different forms of minerals may be more appropriate in specific situations. In critical situations, it is likely that a combination of sources is beneficial.

Not all “specific situations” are well-defined. However, in Tennessee, because of the Forage Mineral Survey presented in this publication, there has been progress toward defining our “specific situation.”

In Tennessee, given the significant levels of antagonistic factors identified by the 2001-2004 Forage Mineral Survey, there is apparently a somewhat stronger argument for using organic minerals to meet a portion of beef cattle’s mineral requirements.

The organic forms of some of the trace minerals may be of greater value when an animal is under nutritional, disease or production stress. Since organic forms cost more than traditional inorganic forms, increased production must be obtained for a profit to be realized.

Mineral chelates, complexes and proteinates are not chemically equal. Mineral proteinates will be more variable in their chemical structure, and possibly their physiological function, than a specific amino acid-mineral complex, e.g., zinc methionine. Much work remains to be done to sort out the chemistry, digestibility, bodily function, quality control or product consistency, and economic benefit of the organic forms of trace minerals available today.

Monitoring Mineral Consumption by Beef Cow-calf Herd

It is important to monitor consumption of mineral supplements by the beef herd, especially if mineral-related problems are suspected.

Problems related to mineral consumption may include sudden death of nursing cows (possibly related to magnesium deficiency-grass tetany) or slow breeders (possibly related to copper deficiency, possibly complicated by sulfur, molybdenum or iron excess).

Commercial mineral mixtures typically have suggested consumption rates on the label. If consumption is not within the desired range, problems may occur.

Use the Mineral Consumption Record at the end of this section to monitor consumption of mineral supplements. If consumption is more or less than desired, it may be necessary to discuss the problem with your mineral dealer.

Consumption is particularly critical if the supplement is medicated. Medications should typically be delivered at specific levels. Significant variation from recommended consumption may have negative performance effects.

Monitoring consumption is particularly important when changing minerals. If, for example, a mineral with a higher copper level is being provided to address copper deficiency issues, make certain that animals don't consume significantly more of the supplement than the label suggests. If they consume too much of a high-copper mineral, the risk of copper toxicity increases. Copper toxicity is not common in beef cattle, but it is always wise to avoid toxicity possibilities.

Expect moderate variation in mineral consumption. Many factors affect consumption (season, pasture moisture, location of mineral feeder, etc.) Cows with young calves typically consume more. As calves grow, they also consume mineral. It is advisable to make allowances for some variation, and avoid making significant adjustments unless over- or under-consumption is persistent or significantly different than the label recommends.

Mineral Consumption Record¹

(Number of Cattle)

Date	Amount Fed	Calculations and/or Comments

¹Calculate daily consumption per head (in pounds) by adding consumption over a period, dividing by number of days in that period, then dividing by number of head. To convert to ounces, multiply the result by 16.

SUMMARY

The old adage “if it’s not broke, don’t fix it” is especially appropriate when considering changes in a mineral supplementation program. However, if production problems exist that are rooted in the mineral program, information exists to allow logical decisions to be made and practical solutions to be found.

Research and observations from the field emphasize, more than ever, the delicate balance among minerals that is necessary if biological efficiency is to be realized. It’s easy to consider only one mineral at a time without giving due attention to interactions among minerals affecting individual mineral use and requirement.

On the other hand, do not become apathetic just because the problem is complex and all the answers are not known. There are more answers today than ever and more are being discovered all the time. Minerals are no more important in good nutrition today than they have ever been, but today there are additional data to show that problems in production, especially in the areas of health and reproduction can be corrected, with proper mineral supplementation.

As a result of the Tennessee Forage Mineral Survey, beef producers have considerable information available for making decisions. Even more importantly, the companies that manufacture and sell mineral supplements for beef cattle have taken the information from the survey and reformulated their products to better reflect the needs of Tennessee cattle.

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