ASSESSING AND IMPROVING THE MINERAL STATUS OF TENNESSEE BEEF CATTLE

Warren Gill, PhD, Aaron Fisher, MS, Clyde Lane, PhD,
Chris Richards, PhD, Debbie Joines, BS, Jim Neel, PhD

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In 1996, the beef CHAPA (Cow/Calf Health and Productivity) audit was released. This report detailed many of the deficiencies and imbalances that existed in forages in our region, and alerted the authors to the potential role of these nutrient imbalances in numerous problems with beef cattle in Tennessee. These problems include rough hair coats, decreased breeding efficiency and a variety of pathologies associated with compromised immune function (scours, pneumonia, bovine respiratory disease complex, etc.).

As early as 1998, it began to appear as if the problems were more serious in certain parts of the state. A number of producers in Montgomery county, for example, were reporting that the hair coats of their cattle were rough, they were having problems with getting cattle bred. One producer, who retained ownership of his cattle in western feedlots, found that his cattle, which had been carefully vaccinated by a local veterinarian, were still getting sick when shipped. They pulled blood and found there were low levels of both copper and selenium. He was using a mineral considered to adequate (at that time) in copper and selenium. When forages were tested, they were found to be low in copper, and very high in sulfur (sulfur "ties up" both copper and selenium).

As reports of these problems increased, it became clear that efforts must be made to learn more about the specific mineral deficiencies that were involved and to develop strategies for improving the mineral status of Tennessee beef cattle.

Starting in 2001, after funding was obtained, beef producers in Tennessee worked closely with the University of Tennessee Agricultural Extension Service in assessing the mineral status of their forages and their cattle herds.

The Problem(s)

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).

Results of The 2001 - 2004 Tennessee Forage Mineral Survey

In an effort to more effectively evaluate the mineral status of Tennessee pastures, Extension agents across the state were asked to collect samples of pasture forage where beef cattle were grazing. These samples were processed under the cooperative supervision of Debbie Joines, Director of the University of Tennessee Soil Testing Laboratory, and John Franklin, Supervisor of the Tennessee Farmer's Cooperative Testing Facility.

Results of the survey were interesting, and in many ways, unexpected. They have been particularly important to producers who desire to improve production efficiency. The Forage Mineral Survey showed:

- **Copper (Cu) levels were in the deficient range.** The desired level of copper in forages is 10 ppm (NRC, 1996). It was not a surprise that copper concentrations were low (see table 1). However, levels were significantly ($P < 0.05$) lower in late summer / fall (Especially in 2001 and 2003). This is consistent with work from Virginia Tech (Saker et al., 1998) which showed that the endophyte fungus (*Neotyphodium coenophialum*) commonly found in Kentucky 31 tall fescue is associated with lower copper availability.
- **Sulfur (S) levels were high.** Sulfur causes copper to be less available 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% are considered antagonistic).
- **Magnesium (Mg) levels were low in the spring while Potassium (K) levels were surprisingly high**. Low Mg was expected as this has been known as the single most important risk factor in grass tetany. What was more revealing was the *high concentration of potassium*, which is known to interfere with availability of magnesium. Approximately one fourth of the potassium levels were above 3%, which is considered high enough to increase the risk of grass tetany. In the spring, almost 1/3 of the samples were high in K.
- **Zinc (Zn) was marginally low**, **with Phosphorus (P), Calcium (Ca) and Manganese (Mn) within Acceptable levels**. Zinc was low enough to be routinely included in mineral supplements. Phosphorus was not as low as anticipated. This may allow mineral mixtures to be formulated with slightly lower levels of Phosphorus. 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.

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 1. Copper (Cu) was at least marginally deficient in 92.4% of the samples and sulfur (S) was considered at least marginally antagonistic to copper in 89.3% of the samples. Zinc was classified at least marginally deficient in 83.1% of the forage samples. In 23.0% of the samples, potassium was above the maximum tolerable concentration. Forage Cu levels are low and are lower in the fall than in the spring. Forage S levels are often high enough to be antagonistic to copper utilization, and are higher in the fall than in the spring. Magnesium levels are lower and potassium levels are higher in the spring than the fall. Results indicating year and season variation in forage minerals could provide basis for improving mineral nutrition of beef herds.

Table 1. Means of forage mineral levels 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 $P < 0.05$.

Table 2 reveals the levels at which forage minerals are considered adequate, marginally deficient or deficient. This could be helpful in understanding the data from table 1. In many cases it is as important to understand when levels are too high. This information is also in Table 2 in reference to sulfur and potassium because these were the minerals found to be most often in excess in the Tennessee Forage Mineral Survey

Table 2. Classification of trace minerals and antagonists in forages.
(Mortimer, 1999; NRC, 1996)

Trace Minerals	Deficient	Marginally Deficient	Adequate	MTC*
Copper, ppm	<4	4-9	>9	100
Zinc, ppm	<20	20-29	>29	500
Manganese, ppm	<20	20-39	>39	1000
Selenium, ppm	<0.1	0.101-0.199	>0.199	2

Antagonists		Antagonistic Level			
	Deficient	Ideal	Marginal	High	MTC*
Sulfur, %	<0.10	0.11-0.20	0.21-0.30	0.31-0.39	>0.39
Potassium, %					>3

* Maximum Tolerable Concentration

Hair Coat Score

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.

Care should be taken when evaluating the hair coat of cattle, because it changes throughout the year. For example, in the late 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 be a cause of 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 any mineral deficiencies and/or imbalances by helping beef cattle producers objectively evaluate the hair coats of their beef herd. It is listed in Table 3 below.

Table 3. 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%)of body; slow shedding
5	Hair clearly dead in appearance; brittle; cattle not slicking off normally

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

Blood / Tissue Testing

Table 4 lists the number of samples, means and ranges for serum copper and selenium samples taken in Tennessee during 2002. Table 4 lists the ranges used to characterize the serum copper and selenium levels. The blood samples were taken from approximately 20 cow herds and a portion of the bulls consigned to the University of Tennessee Central Bull Test Station. The below blood levels confirm the existence of problems and allow individual producers to assess

their situation.

Table 4. 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 5. 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. Remember, however, that the 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 extreme 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.

Steps to Solving Mineral Problems

The imbalances revealed in the 2001-2003 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 (This is provided on the label or by mineral dealer).

3. Work with your mineral dealers. Ask questions. Data from the Tennessee Forage Mineral Survey has been shared with all mineral dealers that 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. Ask questions; 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 be 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 discussed in the preceding text, Potassium levels were higher than expected. This should be fair warning to beef producers to not 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 (See Table 5) 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 deficiency could be a problem, if not properly supplemented. Selenium analysis is difficult, so only thirty samples were analyzed for selenium in the Forage Mineral Survey. Over 93% 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 which 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 the Food and Drug Administration (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.

8. If it ain't broke, don't fix it. If calving rate is good (90 to 95% calf crop), cattle have healthy coats of hair and there is little sickness, there may not be a need to change the mineral

program. Everyone does not need to change; but this information will provide a basis for examining production efficiency and evaluating mineral supplementation strategy.

Table 6. Suggested copper levels in mineral supplements based on various conditions; assuming consumption of 3-4 ounces of mineral supplement per cow per day.

Scenario	Forage Copper (ppm)	Forage Sulfur (%)	Suggested Level of Copper in Mineral (ppm)
No obvious problems	10	0.2	700 - 1000
Some rough hair coat	8	0.25	1000 - 1200
Rough hair, slow breeders & some open cows	6	0.3	1500 - 2000
[1]Rough hair & more difficult and significant breeding problems	< 6	> 0.31	2000 - 3000

[1]This scenario is included to emphasize that there are extreme situations in Tennessee which may require higher than usual levels of copper supplementation. Work with Extension agents and mineral suppliers to develop solutions to difficult problems. This may include developing a custom mineral mixture; typically available, but requiring ordering in larger bulk quantities.

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 levels for mineral supplements.

Table 7. Example Mineral Supplement for Beef Cows on Fescue[1]

	Intake/head/day	
Element	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)

[1]Note: 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.)
[2]Increase magnesium during periods when cattle are susceptible to grass tetany.
[3]Sulfur is often in excess in Tennessee and may be deleted completely; except sulfur is often "accidently" included as part of other mineral (such as Copper Sulfate)
[4]These 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% 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 (Table 1), and potassium levels are often high (Table 1), it is probably advantageous to maintain at least twenty 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).

For more information on the Tennessee Forage Mineral Survey, see our website: http://animalscience.ag.utk.edu/forageminerals/Default.htm

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