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Making Sense of Mineral Supplementation

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INTRODUCTION

Mineral nutrition is one of the most complicated and least understood components of nutrition. For years, producers and researchers alike have known about the need for mineral supplementation; however, development of mineral supplements to meet the requirements of grazing cattle often becomes a difficult and challenging problem due to 1) changes in animal requirements with stage and level of production, 2) differenc in forage supply of minerals, and 3) methods to supply cost-effective supplemental minerals that ensure adequate intake and bioavailability (Greene, 1999).

MINERAL REQUIREMENTS

For most producers the place to begin development of a mineral program is simply identifying the animals' requirements. Table 1 provides an overview of mineral requirements for growing and finishing cattle as well as gestating and lactating cows. These requirements should be viewed as a baseline for developing supplementation programs. As shown, the requirements for calcium, phosphorus, and sodium are provided as ranges. The requirement for these nutrients increases with increasing weight and milk production. As such, producers should work with their nutritionist or consult the Nutrient Requirements of Beef Cattle publication to develop more detailed requirements for their herd.

Table 1. Mineral requirements of beef cattle[a]

Mineral	Growing and finishing	Cows	
		Gestation	Early lactation
Calcium (%)	.40-.80	.16-.27	.28-.58
Cobalt (ppm)	.10	.10	.10
Copper (ppm)	10.0	10.0	10.0
Iodine (ppm)	.50	.50	.50
Iron (ppm)	50.0	50.0	50.0
Magnesium (%)	.10	.12	.20
Manganese (ppm)	20.0	40.0	40.0
Phosphorus (%)	.22-.50	.17-.22	.22-.39
Potassium (%)	.60	.60	.70
Selenium (ppm)	.10	.10	.10
Sodium (%)	.06-.08	.06-.08	.10
Sulfur (%)	.15	.15	.15
Zinc (ppm)	30.0	30.0	30.0

[a]Adapted from NRC (1996).

It is important to recognize that while these requirements are based on years of published research, our understanding of mineral nutrition in beef is cursory at best. A growing body of research suggests that mineral requirements can vary significantly by breed, production, and the presence of antagonists. Producers should work with their nutritionist or Extension personnel to adjust their mineral program accordingly to account for these factors.

ANALYSIS OF HERD MINERAL STATUS

Mineral status can have a tremendous impact on the response to supplementation. If an animal's mineral stores are adequate, it is unlikely that supplementation will result in a biologically or economically significant response. However, if an animal is in a deficient state, and production has been compromised, the response to supplementation can be dramatic.

The first step in determining mineral status of the cowherd is to objectively analyze various performance and production measures. If there appears to be a reduction in a particular measure, be sure to rule out other potential causative factors. For example, if conception rates are significantly lower than in past years, be sure to evaluate body condition and health of the females before investing in a more expensive mineral program. Many signs and symptoms of mineral deficiencies are non-specific and can be caused by numerous other conditions or diseases. It is also essential to evaluate the current mineral program. Is it well balanced? What percentage of the cow's requirements does it meet? And, perhaps most importantly, are the cows consuming enough? The solution to the problem may be as simple as including a small amount of molasses to the mineral supplement.

The second step in determining mineral status is to determine how much of each mineral is supplied by the diet. Because of the inherent variability in the mineral content of the feeds and the potential error associated in predicting feed and water intake of the animal, this estimation can be challenging. Nonetheless, it is critical to developing a cost-effective mineral program.

Tables 2 and 3 contain mineral concentrations of native forages in the Northern Great Plains and meadow hay from the Sandhills of Nebraska. These tables illustrate three key points. First, they illustrate the variability in forage mineral concentrations. Next, they demonstrate the reduction in concentration of some minerals as forages mature and eventually senesce. Finally, the tables suggest that the mineral content of forages may be sufficient to meet a significant portion of the cow's needs. Forages should be sampled and analyzed for mineral concentration periodically throughout the year to facilitate appropriate modifications to the mineral program.

Table 2. Mineral concentrations of live and dead tissue samples in the Northern Great Plains[a]

Mineral	Western wheatgrass		Warm-season grasses		Annual brome	
	Live	Dead	Live	Dead	Live	Dead
	% of DM					
Ca	.25*	.22	.34	.32	.35*	.23
P	.16*	.07	.20*	.10	.32*	.09
Mg	.12	.07	.16	.10	.23	.09
K	1.6*	.3	1.0*	.3	2.7*	.3
	ppm					
Zn	20*	15	30	21	24*	17
Cu	2	2	5	8	6*	3
Mn	47	49	51	50	97*	66
Mo	1	1	1	2	1	2

[a]Adapted from Grings et al. (1996).
*Within a species and mineral, concentrations differ between live and dead tissue $P < .01$.

Table 3. Mineral concentrations of Sandhills meadow hay samples from three Nebraska counties[a]

Element	Cherry	Rock	Holt
Cu (ppm)	9.4[b]	6.7[c]	6.5[c]
Zn (ppm)	26.1[b]	25.5[b]	27.5[b]
Mn (ppm)	85.9[b]	111.9[c]	131.5[c]
Mo (ppm)	6.1[b]	6.1[b]	6.1[b]
P (%)	.25[b]	.29[b]	.15[c]
Mg (%)	.17[bc]	.19[c]	.16[b]
K (%)	1.1[b]	1.6[c]	1.3[b]

[a]Adapted from Hickock et al. (1996).
[b,c]Means in a row with different superscripts differ ($P < .05$).

We have known for years that cattle will select a higher quality diet than we can clip, even if we watch closely and attempt to clip exactly what they are eating. This fact holds true for some minerals, but not all. Previous research has demonstrated that the diet selected by cattle will be higher in calcium and phosphorus than clipped samples; however, trace mineral concentrations are generally similar between clipped samples and selected diets (Corah, 1995). It is also important to recognize that the minerals contained in feeds and forages may not be 100% available to the animal. As a general guideline, assume that only 50% of the mineral content of feeds and forages is available. When sampling forages, care should be taken to clip forages similar to those being selected by the animal. Try to gather samples from areas where the cattle are grazing and make every effort to reduce contamination of the sample from weeds or dirt.

Water also contributes a significant amount to the mineral nutrition of a beef cow. However, because of the extreme variability in mineral content and intake, most producers should only consider water as a source of potentially detrimental minerals (i.e. sulfur and iron). Producers that wish to take advantage of minerals provided in water should only do so after carefully analyzing the mineral concentrations of each water source for both level and consistency. It is also critical to understand the variation in water intake associated with environmental conditions and level of production. A more detailed discussion of water quality and water intake is provided elsewhere in these proceedings.

The third and final means of assessing mineral status is to directly sample the animal. Mineral status can be evaluated by sampling and analyzing blood and/or tissue. For most minerals, a liver sample is the most reliable means of determining mineral status, especially for trace minerals. Mineral concentrations in blood are generally not good indicators of mineral status unless an animal is severely deficient. Liver samples can be obtained either post-mortem or from a live animal via liver biopsy. The liver biopsy procedure is simple and inflicts very little stress upon the animal. Consult your veterinarian or Extension personnel to find out more information on collecting liver biopsies.

MINERAL SOURCES

Mineral sources can have a dramatic impact on the effectiveness of a mineral supplementation program. Whether evaluating a commercial mineral supplement or developing a custom mineral supplementation program, close attention to the sources used to provide a particular mineral can mean the difference between meeting the cow’s requirements as economically as possible or wasting a significant amount of money.

In general, inorganic sources are the most cost-effective means of supplying minerals to a beef cow. However, inorganic mineral sources are not all created equal. Research suggests that sulfate and chloride forms of various minerals are the most bioavailable, followed by carbonates, with oxides being the least bioavailable. One exception to this rule of thumb is copper oxide. When the powdered or granular form of copper oxide is included in a mineral supplement, it is a very poor copper source. However, research indicates that copper oxide needles, administered as a bolus, can be an extremely effective means of delivering copper to cattle on forage-based diets.

When evaluating a mineral supplement, it is extremely important to read the feed tag carefully to determine the guaranteed amount and source of each mineral. In some cases, a mineral source may be listed as an ingredient on the tag without a guaranteed analysis. For example, a feed tag may list manganese sulfate as an ingredient but not provide guaranteed analysis for manganese. In this situation, producers should err on the side of caution and assume that there is essentially no manganese in the mineral supplement. Also, as mentioned previously, mineral sources vary significantly in their bioavailability. This is a critical consideration when evaluating different mineral supplements. For example, if a rancher were considering “Mineral A” which contains 1200 ppm copper as copper sulfate and “Mineral B” which also contains 1200 ppm copper, but supplied it as copper oxide, he would be much better off with Mineral A. Copper sulfate is considered to be 100% bioavailable, while copper oxide is only 15% bioavailable. Mineral concentrations and relative bioavailabilities for many common inorganic mineral sources can be found in Table 4.

Table 4. Mineral concentrations and relative bioavailabilities of common mineral sources[a]

Supplement	Mineral concentration (%)	Relative bioavailability[b]
Calcium		
Calcium carbonate	*38*	*100*
Calcium chloride	31	125
Dicalcium phosphate	20	110
Limestone	36	90
Monocalcium phosphate	17	130
Cobalt		
Cobaltous sulfate	*21*	*100*
Cobaltic oxide	73	20
Cobaltous carbonate	47	110
Cobaltous oxide	70	55
Copper		
Cupric sulfate	*25*	*100*
Cupric chloride (tri-basic)	58	115
Cupric oxide	75	15
Iodine		
Potassium iodate	*69*	*100*
Calcium iodate	64	95
Ethylenediamine dihydriodine (EDDI)	80	105
Magnesium		
Magnesium sulfate	*20*	*100*
Magnesium oxide	55	100
Manganese		
Manganese sulfate	*30*	*100*
Manganese carbonate	46	30
Phosphorus		
Defluorinated phosphate	12	80
Dicalcium phosphate	18	85
Selenium		
Sodium selenite	*45*	*100*
Sodium		
Sodium chloride	*40*	*100*
Sodium bicarbonate	27	95
Zinc		
Zinc sulfate	*36*	*100*
Zinc carbonate	56	60
Zinc oxide	72	100

[a]Adapted from Hale and Olson (2000).
[b]Relative bioavailability is expressed relative to the source listed first (italicized) for each mineral.

Organic mineral sources represent another option for producers to supply minerals to their cowherds. Research suggests that some organic mineral sources are indeed more bioavailable; however, production responses to supplementation have been extremely variable. Positive responses to organic mineral supplementation are most likely during stressful periods in the production cycle (i.e. calving and weaning), or when mineral antagonists (i.e. sulfur, molybdenum, iron, or aluminum), are present in large amounts. In these situations, producers should objectively weigh any expected benefit to animal performance against the added cost of including organic minerals in their supplementation program.

Commercial mineral supplements are commonly formulated to include 1/3 to 1/2 of the key minerals from organic sources, which will generally add 15% to 20% to the cost. For example, a commercial mineral supplement formulated to meet 100% of the NRC requirements for a beef cow, using all inorganic mineral sources might cost $580 per ton. Using the same formulation, but supplying 1/2 of the mineral from organic sources increases the cost to $680 per ton, an increase of 17.2%.

DEVELOPING COST-EFFECTIVE MINERAL PROGRAMS

When developing a mineral program, producers should consider the requirements for the cowherd based on weight and stage of production, mineral intake of their cowherd (forage intake and mineral concentration), and evaluate the most economical means of supplying any needed minerals.

Without question, the most expensive mineral to supplement is phosphorus. In some cases, the most economical means of supplying phosphorus is simply feeding a protein supplement. Depending on the level of phosphorus required and the concentrations in the forage and protein supplement, additional phosphorus from a mineral supplement may not be necessary. Table 5 contains the phosphorus concentrations and the amount of phosphorus supplied to the diet by various commodity protein sources.

Table 5. Percent phosphorus contributed to diet by feedstuffs fed at various levels[a]

Feedstuffs	% P in feedstuff[b]	lb fed per day		
		2	4	6
		----------- % P contributed to diet -----------		
Canola meal	1.20	.09	.18	.27
Corn gluten feed	.95	.07	.14	.21
Cottonseed meal	.76	.06	.11	.17
Dried brewers grains	.70	.05	.11	.16
Dried distillers grains	.83	.06	.12	.19
Soybean meal	.71	.05	.11	.16
Sunflower meal	1.02	.08	.15	.23
Wheat middlings	1.00	.08	.15	.23

[a]Calculations are based on a 1200 lb cow consuming dry matter at 2% of body weight.
[b]From Nutrient Requirements of Beef Cattle, Seventh Edition, National Research Council, 1996.

Early research at the King Ranch in Texas report tremendous performance and reproductive benefits to phosphorus supplementation (Herd, 1997). However, more recent research from USDA demonstrated only slight improvements in weaning weights and no significant effect on reproduction (Karn, 1995, 1997). This difference in response is likely due to the phosphorus concentration in the basal forage and further emphasizes the need for feed and forage analysis. Table 6 outlines the % phosphorus needed in a mineral supplement to meet the requirements of cows in different stages of production consuming diets (feeds and forages) of various phosphorus concentrations.

Table 6. Supplemental phosphorus levels necessary to meet NRC requirements of cows at different stages of production consuming diets containing various phosphorus concentrations[a,b]

	Total diet P, %				
	.05	.10	.15	.20	.25
	------------------ % P needed in mineral supplement ------------------				
Maintenance					
1000 lb BW	8	6	6	6	6
1100 lb BW	10	6	6	6	6
1200 lb BW	10	6	6	6	6
1300 lb BW	12	8	6	6	6
1400 lb BW	12	8	6	6	6
Gestation					
Last 1/3	16	10	6	6	6
Lactation					
10 lb of milk/day	16	10	6	6	6
20 lb of milk/day	16	16	10	6	6
30 lb of milk/day	16	16	16	8	6

[a]Adapted from Paisley and Hill (2000). Many of the 6% P situations may actually be in excess, but due to irregularities in mineral consumption and some carrier needed for trace minerals, a 6% P mineral is recommended. Intake assumptions: 2% of body weight as dry matter during gestation and maintenance, during lactation intake increases proportionally to milk production and body weight based on MARC data.
[b]Adapted from NRC, 1996.

If the cowherd is not under production stresses and antagonists are not a problem, supplementation above requirements is costly and generally unproductive. This is especially true for phosphorus. If, after determining the cow’s requirements and analyzing each feed and forage for phosphorus concentration, a producer determines they don’t need the typical 12-12 mineral, there is a tremendous opportunity for cost savings. It has been suggested that each 1% change in phosphorus level results in an $11/ton change in the price of the mineral. In other words, reducing from a 12% phosphorus mineral to an 8% phosphorus mineral results in a $44 per ton savings in mineral expense.

Ideally, producers should work with their nutritionist or Extension personnel to create a program tailored specifically to their production system and have mineral supplements custom made. However, this is not always practical or economical. Therefore, it is possible to significantly reduce mineral expense by supplementing strategically throughout the year. The only “mineral” that needs to be supplemented throughout the year is common white salt. Cattle have an appetite for salt and can regulate their intake according to need. This is not the case with other minerals. Cattle do not have the “nutritional wisdom” to identify deficiencies and consume the appropriate mineral to address the need. Other than white salt, minerals should be supplemented according to need. Depending on the mineral concentrations of the diet, it is quite likely that supplementation will only be required from 45 days prior to calving through the breeding season. This period is when the cow is experiencing her greatest demand for nutrients combined with the stress of calving. During this period, producers should provide at least 75%, but not more than 125% of the NRC requirements. Table 7 outlines the amount of each trace mineral that should be contained in a mineral supplement to provide 75%, 100%, or 125% of the NRC requirements for a beef cow consuming dry matter at 2% of her body weight. Organic mineral sources may also be appropriate during this period; however, they should only be included to provide 50% or less of the supplemental mineral. The only exception to these guidelines would be the presence of an antagonist, in which case, higher levels may merit consideration.

Table 7. Trace mineral inclusion rates for mineral supplements formulated to meet 75%, 100%, or 125% of the NRC requirements[a,b]

Daily intake (oz)	Mineral					
	Co	Cu	I	Mn	Se	Zn
	ppm					
75% of NRC requirement						
2	14.4	1440	72	576	14.4	4320
3	9.6	960	48	384	9.6	2880
4	7.2	720	36	288	7.2	2160
100% of NRC requirement						
2	19.2	1920	96	7680	19.2	5760
3	12.8	1280	64	5120	12.8	3840
4	9.6	960	48	3840	9.6	2880
125% of NRC requirement						
2	24	2400	120	9600	24	7200
3	16	1600	80	6400	16	4800
4	12	1200	60	4800	12	3600

[a]Calculations are based on a 1200 lb cow consuming dry matter 2% of body weight.
[b]Adapted from NRC, 1996.

Utilizing strategic supplementation, producers may be able to cut their mineral expenses nearly in half. Assuming mineral supplementation begins February 1 and continues through July 1, and the cows consume $400 per ton mineral at 3 oz per head per day, the cost amounts to $5.63 per cow. If the same mineral supplement was used for the entire year at an average of 2 oz per head per day, the cost would be $9.13 per cow. On a 500 head cow/calf operation that amounts to a $1750 savings. Altering the composition of the mineral to account for changes in requirements and mineral content of the diet may help reduce that expense further.

CONCLUSION

Developing the most cost effective mineral program is certainly not a formula that can be applied to every farm and ranch around the country. Producers must evaluate their production system, its resources, level of production, and production constraints, to develop the most cost-effective program for their operation. Keep in mind that more expensive mineral supplements do not always correlate with increased production or performance. Any cost associated with change in a mineral program must be accompanied by a corresponding increase in production or performance (i.e. weaning rate, weaning weight, etc.) to offset the added expense.

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