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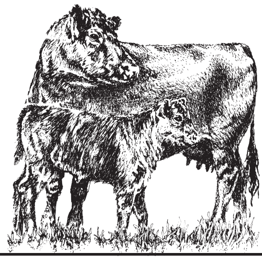

Western Beef Resource Committee — *Fourth Edition*

Cattle Producer's Handbook

Nutrition Section 327

Mineral Supplementation of Beef Cows in the Western United States

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The beef cattle industry in the western United States is dependent on forage production. However, forage alone does not always provide all the essential minerals necessary to maintain a healthy and productive cowherd. This makes necessary mineral supplementation of beef cattle consuming standing or harvested forage to maintain optimal reproductive efficiency, immunity, lactation, and growth.

Minerals are commonly classified as either macro or micro (also known as trace) minerals. The macrominerals are calcium, phosphorus, potassium, magnesium, sodium, chlorine, and sulfur, while the common microminerals are iron, manganese, zinc, copper, iodine, selenium, cobalt, and molybdenum.

Developing a mineral supplementation program to meet the requirements of cattle consuming a forage-based diet can be difficult. This is primarily because of challenges associated with (1) changes in animal requirements with the stage and level of production, (2) differences in the concentration of minerals in the forage, and (3) providing a mineral supplement in such a way as to ensure adequate intake and bioavailability (Green 2000).

A balanced mineral program should be supplied year-round during all stages of production. A prime example is supplementation of copper, which is low in milk. Thus, the cow must build liver copper stores in calves during gestation to minimize the potential for deficiency after birth. Without proper trace mineral supplementation before parturition, health disorders can occur, such as embryo mortality, stillbirths, retained placenta, mastitis, calf scours, pneumonia, apparent vaccine failure, and general reproductive problems can occur (low numbers of cows exhibiting estrus, poor conception rate, etc.).

In addition, it may require an extended period to raise deficient levels. Davy et al., (2016) found that it took 90 days to move a selenium-deficient herd average to sufficient levels using a salt-based supplement with a high selenium level. Even then, nearly half the cattle were still below optimal levels, indicating that supplementation only during the breeding season would not be sufficient.

Mineral Requirements

Native range in most areas of the western United States is deficient in one or more minerals and, therefore, a properly formulated mineral program is warranted. The mineral requirements of dry and lactating beef cows are presented in Table 1. To properly formulate a mineral

Table 1. Generally accepted beef cow mineral requirements.

	2016 beef NRC requirements[a]	
Mineral	**Dry cow**	**Lactating cow**
Macrominerals (%)		
Calcium	0.14	0.28
Phosphorus	0.10	0.16
Potassium	0.60	0.70
Magnesium	0.12	0.20
Salt	0.07	0.10
Sulfur	0.15	0.15
Trace minerals (ppm[e])		
Iron	50	50
Manganese	40	40
Zinc	30	30
Copper	10	10
Iodine	0.50	0.50
Selenium	0.10	0.10
Cobalt	0.15	0.15

[a]Requirements are based on the current beef NRC (2016). In addition, the values are expressed as a proportion of the total diet.

[b]ppm = parts per million

mix, the beef producer must have an estimate of mineral status of the cowherd.

The gold standard for mineral sampling is a liver biopsy because most minerals are stored in the liver. However, this is an invasive procedure requiring a trained veterinarian. The next best method is blood sampling cattle (Kirk et al. 1995; Pavlata et al. 2001), which can be collected from either the tail or the neck. Blood sampling is rapid and fairly inexpensive to analyze.

Critical to obtaining accurate results is the timing of blood sampling. Since most minerals are stored in the liver, the stored mineral must be depleted from the liver before it is shown to be deficient in a blood sample. A mineral that has recently become deficient in the diet, which can happen when cattle are moved to a new forage source, may falsely show adequate in a blood sample since its deficiency is recent. To avoid this, cattle should be sampled after they have been exposed to the same forage source for several months.

Selenium should be sampled as whole blood, while most all other minerals need to be submitted as serum (Maas et al. 1992), which will require a centrifuge to spin the samples. Rubber collection tubes contain zinc, thus giving a high reading of zinc when used for sampling. If an accurate zinc test is desired, plastic trace element tubes (blue top) should be used.

Table 2 shows the critical range recommended in toxicology reports from the UC California Animal Health and Food Safety Lab for blood test results for most minerals tested. A subsample of the herd containing 10 to 15 animals is a generally adequate starting point to obtain a representation of a herd's mineral status if equivalent forage sources and supplement programs exist within the population. Most herds that have had a consistent supplement program administered to the same animals beyond a 6-month period show low variance among animals, particularly cows (Davy unpublished data).

If initial screening shows high variance, however, then additional testing of more animals can help determine the reason. For example, large variances often indicate a low level of mineral consumption, or that the level of a particular mineral in the supplement is not high enough. Follow-up sampling quantity can obviously vary depending on the size and differing locations of a herd.

Table 2. Critical mineral levels for blood sampled cattle. Proper levels fall within the low and high range. This table is based on toxicology reports from the UC California Animal Health and Food Safety Lab.

Mineral	Sample type	Low below	High above	Unit
Selenium	Whole blood	0.08	0.5	ppm
Copper	Serum	0.8	1.5	ppm
Calcium	Serum	80	110	ppm
Magnesium	Serum	18	35	ppm
Phosphorus	Serum	45	60	ppm
Potassium	Serum	3.9	6	mEq/L
Sodium	Serum	135	150	mEq/L
Zinc	Serum	0.8	1.4	ppm
Manganese	Serum	6	70	ppb

Forage sampling has been a common method used to estimate mineral deficiencies. The difficult part of this method is that it can be influenced by soil characteristics, plant species, sampling date (year and month), sampling location, and annual precipitation (Sprinkle et al. 2000; Toombs et al. 2000; Ganskopp and Bohnert 2003). Fig. 1 further illustrates this point.

The data presented in Fig. 1 were adapted from the results reported by Ganskopp and Bohnert (2003) and Sprinkle et al. (2000) for native range in Oregon and Arizona, respectively. It should also be noted that cattle normally select plants and/or plant parts that are higher in nutrient content than clipped forage. Consequently, cattle diets may contain greater quantities of nutrients (CP, minerals, vitamins, etc.) than a forage sample would suggest.

With so many variables to account for in estimating deficiency with a forage clipping method, it is often recommended to also test the cattle through liver or blood sampling. Sampling blood and/or liver helps to account for multiple variables by providing a snapshot of mineral status of the animals at a specific point in time. However, as noted previously, assessing mineral status through blood and liver sampling does not give a good estimate for the consequences of the current diet of the cattle or the diet they may have access to in the near future. Therefore, when assessing mineral status for consideration in developing a mineral supplementation program, it is best to utilize all available information including both blood/liver and soil/forage mineral concentrations because information from any one of these individually is rarely conclusive.

Recent research from California and Oregon concerning mineral supplementation of gestating beef cows has resulted in some interesting data that may alter future mineral supplementation strategies. In California, researchers are beginning to examine manganese levels in cattle. This is an important research area because manganese levels influence reproductive success of cows and health of calves born from manganese deficient dams (Hidiroglou 1979).

While manganese testing is available through veterinary diagnostic labs, manganese is not one of the minerals included in the common trace element screen. Therefore, little is known about manganese status of cattle throughout California, but researchers hypothesize that cattle are typically deficient.

In Oregon, late-gestation beef cows were supplemented with organic or inorganic sources of cobalt, copper, zinc, and manganese, above current

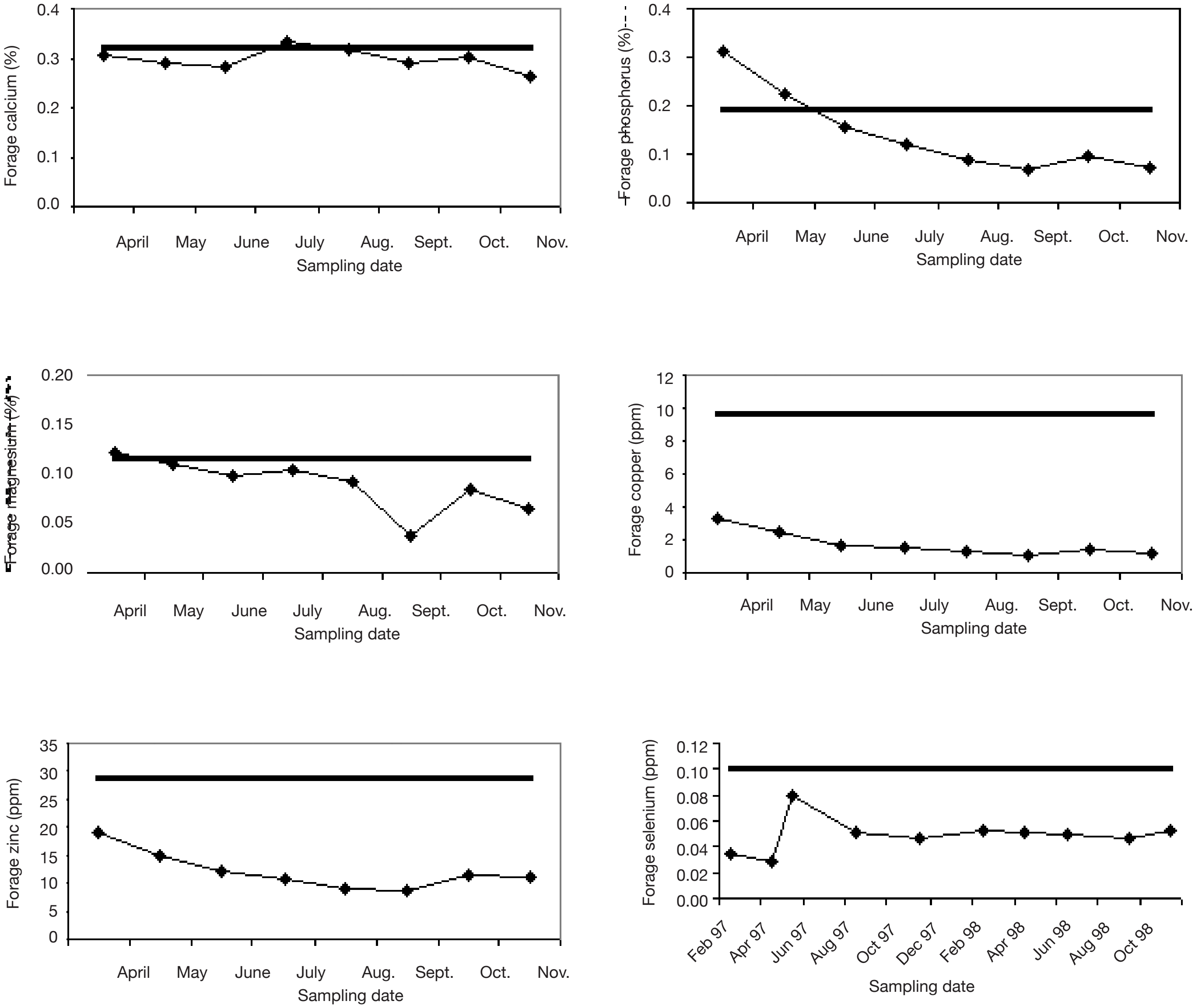

Fig. 1. Monthly forage mineral concentration of native range in southeastern Oregon (calcium, phosphorus, magnesium, copper, zinc) and southeastern Arizona (selenium). The solid horizontal lines indicate the forage mineral concentration necessary to meet the requirements of a 5-year-old, 1,000-pound Angus x Hereford cow that has a body condition score 5, is 60 days pregnant, 120 days in milk, and consuming 25 pounds of forage dry matter per day (NRC 1996; adapted from Ganskopp and Bohnert 2003 and Sprinkle et al. 2000).

requirements, resulting in increased liver concentrations of Co, Cu, and Zn compared with cohorts supplemented at current recommended levels (control; Marques et al. 2016). The resulting calves from organic and inorganic supplemented cows were approximately 50 and 25 pounds heavier, respectively, at weaning compared with calves from control cows, which is suggestive of fetal programming effects on postnatal offspring growth. However, the physiological mechanism underlying these effects, including the role of each specific trace mineral on fetal development and programming, requires further investigation.

Mineral Supplementation

If a beef producer is concerned that their forage source has a severe mineral deficiency, they should consult a nutritionist and veterinarian to have their herd's mineral status determined before providing a mineral supplement that contains high concentrations of minerals. Once an estimate of the mineral content of the whole blood, serum, or liver tissue is obtained, it can be compared with the desired dietary concentration to formulate a successful mineral program.

Mineral toxicities can occur without the proper formulation of a mineral supplementation program, often resulting in poor cow performance, increased morbidity, and potentially death. Minerals can be supplemented by a variety of methods. Animals in confined feeding operations, such as poultry units, feedlots, and dairies, receive formulated or mixed rations, which can be supplemented directly. However, cattle on range, foothill pastures, or permanent pastures cannot be supplemented in this manner due to economics and logistics. The available means to supplement cattle in these extensive grazing units is more limited and relies on the use of salt-mineral mixes, molasses-based supplements, rumen boluses, or the use of injectable products.

The help of a nutritionist in ration formulation for balancing minerals is essential due to interactions between minerals. For example, copper is one of the most commonly affected nutrients by interactions with other minerals. It has been suggested that the recommended level of copper should be raised above that listed as the requirement anytime dietary molybdenum exceeds 2 ppm (parts per million), sulfur exceeds 0.3 percent, iron exceeds 250 to 300 ppm, or some combination exists in the feed and water supply (Herd 1997).

Likewise, high sulfur levels, commonly found in water sources or sulfate fertilized pastures, can also exacerbate selenium deficiency. In addition, low dietary calcium and/or high dietary potassium has been involved with grass tetany (hypo-magnesia) as indicated by the so-called "tetany ratio" (diet potassium concentration divided by the sum of the diet calcium and magnesium concentration; equivalent basis). If this ratio is greater than 2.2, the diet is classified as tetany-prone. Thus, a low content of calcium and/or magnesium (or high potassium) could create a ratio greater than 2.2.

Supplementing with a Salt-based Method When Cattle Are Grazing Range or Pasture

If a beef producer is providing a protein or energy supplement to their cattle, mixing minerals with the supplement is an excellent way to supply minerals to the cowherd on a regular basis. However, this is not practical or warranted in many situations. For example, a beef producer providing alfalfa hay as a protein supplement cannot incorporate the mineral mix with the alfalfa in an effective manner.

Also, cows grazing late-spring to early-summer range in the western United States normally don't require additional protein or energy to maintain acceptable levels of performance. Consequently, the most popular method of providing minerals to beef cattle is through free-choice mixtures. The main problem associated with providing a mineral mix free choice is the regulation of mineral intake. Beef producers cannot rely on their cattle to consume minerals when they need them and leave them alone if they don't. Mineral nutrition of cattle must be managed the same way their protein and energy needs are managed.

A common occurrence observed with cattle that haven't had access to a mineral mix for an extended time is that they will consume several times the recommended level of a given supplement. This is a normal occurrence that should be allowed for about 2 weeks before attempting to regulate intake.

Adding a small amount of salt to a mineral mix will normally encourage supplement intake. However, before adding salt you should determine the concentration in the mineral mix. If the mineral contains 50 percent or more salt, supplement intake will probably not be increased with additional salt. Also, there are areas in which the grass and/or water contains high levels of salt, which will discourage mineral intake if additional salt is included in the mineral mix.

In these situations, the addition of dried molasses, ground grain (distillers, rice bran, corn, barley, etc.), protein supplements (cottonseed meal, soybean meal, etc.), or vegetable oils at 5 to 15 percent of the mineral mix will usually encourage intake (start low and work up to a level where your cows consume the expected amount of supplement). Also, when providing mineral free choice to cows with calves, make sure that the calves are able to reach the mineral container so that they can have access to the mineral supplement as well.

An example mineral mix for areas deficient in selenium, copper, zinc, and phosphorus is provided in Table 3. This mineral mix may not be the best for all selenium, copper, zinc, and phosphorus deficient areas, but it has been used effectively throughout western rangelands and

Table 3. Sample salt mineral mix for areas needing selenium, copper, zinc, and phosphorus. Reprinted from Trace Minerals for California Beef Cattle: How to supplement minerals (UCCE 2017):
http://animalsciencey.ucdavis.edu/mineralproject/how_to_supplement.htm

	Amount	Amount	Amount
	(%)	(ppm)	(mg/lb)
Calcium	10.0	100,000	45,360
Phosphorus	10.0	100,000	45,360
Copper*	0.5 to 0.7	5,000 to 7,000	2,269 to 3,175
Zinc	0.5 to 0.7	5,000 to 7,000	2,269 to 3,175
Selenium	0.011	106	48
E.D.D.I. (iodine)	0.018	176	80
Magnesium	1.0	10,000	4,536
Manganese	0.1	1,000	454
Salt	20.0	200,000	90,720
Iron	0.1	1,000	454
Sulfur	1.0	10,000	4,536
Cobalt	0.002	20	9
Iodine	0.01	100	45.4

***Note the level for copper is higher than generally regarded as safe. The copper levels in this mineral mix may be toxic in areas with adequate or marginal copper levels and/or areas without interfering compounds.** When beginning copper supplementation, initial levels are usually not greater than 0.3 percent. Monitoring of cattle is used to adjust copper level to an appropriate amount.

will be a helpful place to begin for producers who are grazing cattle in an unfamiliar area (Drake pers. comm.).

Bioavailability of Supplemented Minerals

When designing or purchasing a mineral supplement beef producers should be aware of the sources of mineral that are used in the mineral mix. The reason for this is that not all sources of a given mineral are used at the same efficiency by cattle. Organic forms of minerals, most commonly chelates, but also including proteinates and complexes, have a higher bioavailability (how well an animal uses the mineral source) compared with many inorganic forms (carbonates and oxides). However, organic minerals can be more expensive compared with inorganic minerals.

In addition, some inorganic sources (primarily the sulfates and chlorides) are used effectively by cattle. Herd (1997) suggests that some organic forms of minerals "may be of greater value when an animal is under nutritional, disease, or production stress." As a general rule, the bioavailabilities of inorganic mineral sources follow this order: sulfates and chlorides are similar in bioavailability while both are greater than carbonates which have greater bioavailability compared to oxides (sulfates = chlorides > carbonates > oxides; Table 4).

For example, research has demonstrated that the bioavailability of copper oxide in a mineral mix is extremely poor. Consequently, on first observation a mineral mix may appear to contain adequate copper levels. However, if the source of copper used was copper oxide, the mineral mix will not improve copper status in a cowherd in an acceptable manner. A more bioavailable source of copper would be copper sulfate.

Injections and Boluses

Injectable and bolus forms of mineral supplementation can be convenient because they eliminate issues of consumption, can lessen daily labor in supplementation, and are quickly absorbed. They are commonly used in rugged areas where supplementation with loose salt is not practical. The down side with these methods is that they are generally specific to only copper and selenium, so if other minerals are needed, another method of supplementation will be required. In deficient areas, injections can increase selenium levels for up to 45 days (Genther and Hansen 2014; Maas et al. 1993), whereas intraruminal time-release boluses for either copper or selenium are effective up to a year (Sprinkle et al. 2006; Hemingway et al. 2003; Maas et al. 1994).

While the boluses last longer, injections require less handler time, skill, and restraint of the animal. If providing boluses to highly deficient animals is not an option, an effective solution to quickly bolster levels may be to begin with an injection to quickly boost selenium levels and then offer a free-choice mixture for continued selenium supplementation.

Summary

When deciding on a mineral supplement it is essential that a beef producer should have knowledge of the herd's mineral status. Once this is determined through animal testing and/or diet evaluation, deciding on the appropriate mineral supplementation strategy can be made on a case-by-case basis. The help of an extension agent, veterinarian, and ruminant nutritionist to develop a mineral supplementation program is of great value. All mineral mixes are not created equal; therefore, an understanding of mineral requirements, the labor to supplement, and the interactions associated with certain minerals are all necessary considerations.

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Table 4. Source, empirical formulas, mineral concentrations, and relative bioavailabilities of common inorganic mineral sources.

Supplement	Empirical formula	Mineral concentration	Relative bioavailability	Mineral availability
		(%)	(RV)	(% of DM)
Calcium				
Calcium carbonate	$CaCO_3$	38	100	38.00
Bone meal	variable	24	110	26.40
Calcium chloride (dihydrate)	$CaCl_2(H_2O)$	31	125	38.75
Dicalcium phosphate	$Ca_2(PO_4)$	20	110	22.00
Limestone		36	90	32.40
Monocalcium phosphate	$Ca(PO_4)$	17	130	22.10
Cobalt				
Cobaltous sulfate	$CoSO_4(H_2O)_7$	21	100	21.00
Cobaltic oxide	Co_3O_4	73	20	14.60
Cobaltous carbonate	$CoCO_3$	47	110	51.70
Copper				
Cupric sulfate	$CuSO_4(H_2O)_5$	25	100	25.00
Copper EDTA	variable	variable	95	variable
Cupric chloride (tribasic)	$Cu_2(OH)_3Cl$	58	115	66.70
Cupric oxide	CuO	75	15	11.25
Cupric sulfide	CuS	66	25	16.50
Cuprous acetate	$CuC_2O_2H_3$	51	100	51.00
Iron				
Ferrous sulfate heptahydrate	$FeSO_4(H_2O)_7$	20	100	20.00
Ferric citrate	variable	variable	110	variable
Ferric EDTA	variable	variable	95	variable
Ferric phytate	variable	variable	45	variable
Ferrous carbonate	$FeCO_3$	38	10	3.80
Magnesium				
Magnesium sulfate	$MgSO_4$	20	100	20.00
Magnesium acetate	$MgC_2O_2H_4$	29	110	31.90
Magnesium basic carbonate	$MgCO_3$	31	100	31.00
Magnesium oxide	MgO	55	100	55.00
Manganese				
Manganese sulfate	$MnSO_4(H_2O)$	30	100	30.00
Manganese carbonate	$MnCO_3$	46	30	13.80
Manganese dioxide	MnO_2	63	35	22.05
Manganese monoxide	MnO	60	60	36.00
Phosphorus				
Sodium phosphate	$NaPO_4$	variable	variable	variable
Bone meal	variable	21	100	21.00
Defluorinated phosphate	variable	12	80	9.60
Dicalcium phosphate	$CaHPO_4$	18	85	15.30
Selenium				
Sodium selenite	$NaSeO_3$	45	100	45.00
Cobalt selenite	variable	variable	105	variable
Zinc				
Zinc sulfate	$ZnSO_4(H_2O)$	36	100	36.00
Zinc carbonate	$ZnCO_3$	56	60	33.60
Zinc oxide	ZnO	72	100	72.00

Adapted from Hale and Olson (2001)

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Fourth edition; December 2018 Update