Mineral Deficiencies in Florida and Supplementation Considerations

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Summary

Mineral deficiencies have been and continue to be severe detriments to beef cattle production in Florida. Historically, Florida cattle have suffered from deficiencies of P, Ca, Na, Mg, Co, Cu, Zn, and toxicities of F and Mo. In more recent years Se deficiency, as evidenced by white muscle disease and a "buckling" condition, has been widespread. Evaluating 15 data sets of Florida forages (predominately bahiagrass), the minerals most deficient were P, Na, Cu, Se and Zn, with Ca, Mg and Co found to be borderline-to-deficient depending on location, season, forage species, and year. As a low-cost insurance measure to provide adequate mineral nutrition, a modified "complete" mineral supplement should be available free-choice. The major disadvantage to free-choice minerals is lack of uniform consumption by animals. Factors influencing consumption of mineral mixtures include the following:

(1) soil fertility and forage type
(2) season of year
(3) available energy and protein
(4) individual requirements
(5) salt content of water
(6) palatability of mineral mixture
(7) availability of fresh minerals
(8) physical form of minerals

Introduction

Mineral deficiencies or imbalances in soils and forages have long been held responsible for low production and reproduction problems of Florida beef cattle (Cunha et al., 1964; Becker et al., 1965; McDowell, 1997). Research from other warm climate regions has shown mineral supplementation to increase calving percentages by 20% to more than 100%, to increase growth rates from 10% to 25%, and to reduce mortality significantly (McDowell, 1992; 1997).

The first United States reports of Cu or Co deficiency in grazing cattle originated in Florida (Becker et al., 1965). Nutritional anemia or "salt sick" in cattle, later established as a deficiency of Fe, Cu and Co, was noted as early as 1872 (Becker et al., 1965). Prior to the 1950s, Florida's nutritional deficiencies, as evidenced by low forage and(or) animal tissue concentration or decreased performance, had been established for Ca, P, Co, Cu, Na, Mg, and Fe. In more recent years the problems of Se and Zn deficiency for ruminants have been observed. Zinc deficiency was evidenced by hair loss and skin lesions. Throughout the state of Florida, Se is severely deficient on the basis of soil, forage, blood, and liver analysis, as well as white muscle disease (WMD). White muscle disease is characterized by generalized weakness, stiffness and muscle deterioration, with affected animals having difficulty standing. Calves with WMD have chalky white striations, degeneration and necrosis in the skeletal muscles and heart. In calves the tongue musculature may be affected, preventing suckling. Often death occurs suddenly from heart failure as a result of severe damage to heart muscle. In milder cases (in which calves are stiff and have difficulty standing) dramatic, rapid improvement can result from Se–vitamin E injections.

Since the mid 1980s WMD has been most frequently exhibited as "buckling," feeder calves come off the truck or out of the processing chute with weakness of rear legs, buckling of fetlocks and, frequently, generalized shaking or quivering of muscles. Many calves become progressively worse until they are unable to rise and may appear to be paralyzed. Death loss is high among severe cases, and calves with excitable temperaments appear to be most commonly affected. Post-mortem examination of affected calves reveals pale, chalky streaks in muscles of the hamstring and back. The heart, rib muscles, and diaphragm can also be affected.

As a consequence of modern farming systems, acute deficiencies of most minerals for beef cattle have been reduced in Florida. However subclinical deficiencies, which lower growth and reproduction rates, are affecting beef cattle production. Inadequate minerals can affect the immune response and can increase rates of diarrhea and respiratory conditions. Florida has a 10 to 11% lower calving percentage than the U.S. average. Inadequate mineral nutrition for Florida beef cattle is certainly one reason for less-than-optimum reproductive rates. This paper will discuss forage mineral concentrations in Florida as they relate to deficiencies and free-choice mineral supplementation for cattle.

Mineral Requirements for Cattle

Estimated mineral requirements and factors affecting the mineral content of forages and bioavailability of inorganic and organic (e.g., chelates) mineral supplements are reported elsewhere (McDowell et al., 1992; 1997). Mineral requirements are highly dependent on the level of productivity. Increased growth rates and milk production will greatly increase mineral requirements. Mineral deficiencies that are marginal under low levels of production become more severe with increased levels of production, and previously unsuspected nutritional deficiency signs usually occur as production levels increase.

The criterion of adequacy is important; there is reason to suggest that mineral requirements for optimal immune responsiveness and disease resistance are greater than requirements for growth. National Research Council (NRC) requirements are often based on growth performance and quantities of a specific mineral sufficient to prevent clinical signs of a deficiency. Selenium, Cu, Zn, and Co deficiencies have been shown to alter various components of the immune system. Selenium supplementation has decreased mortality rates in ruminants fed diets low in Se when clinical deficiency signs, such as muscular dystrophy, were not apparent. A 2-year study with beef cows and calves consuming pasture and corn silage marginally deficient in Se (.03 to .05ppm) indicated that bimonthly Se–vitamin E injections reduced calf death losses (4.2 versus 15.3%) from birth to weaning (Spears et al., 1986). Most of the deaths were attributed to diarrhea and subsequent unthriftiness.

For grazing livestock, P is the mineral most likely to be deficient. There are differences of opinion as to P requirements of beef cattle. Phosphorous requirements recommended by the NRC may be too high for grazing beef cattle. In Utah, no difference in average weight gains (.45 kg/day), feed efficiency, or appetite were observed between Hereford heifers fed for 2 years on a diet containing .14% P (66% of NRC recommendation) and comparable heifers receiving the same diet supplemented with monosodium phosphate to provide a total of .36% P. After 8 months on a .09% P diet, however, some appetite reduction and decreased bone density were observed. On the contrary, studies from Florida demonstrated that .12 to .13% P was inadequate for growing Angus heifers in a 525- to 772-day experiment. Animals receiving the low P diet had lower gains (205 versus 257 kg), exhibited pica, and had bone demineralization (Williams et al., 1991).

Adequate intake of forages by grazing ruminants is essential to meet mineral requirements. Factors that greatly reduce forage intake, such as low protein content (<7.0%) and increased degree of lignification, likewise reduce total minerals consumed. Mineral supplementation is much less important for cattle if energy–protein requirements are inadequate. But, when energy and protein supplies are adequate, livestock gain weight rapidly, resulting in high mineral requirements. It is therefore uneconomical to provide mineral supplements to grazing cattle if the main nutrients they are lacking are energy and(or) protein.

Florida Mineral Deficiencies

Table 1 (macrominerals) and Table 2 (trace minerals) illustrate forage mineral concentrations from 15 data sets from different regions in Florida, compared to critical concentrations. Data are presented by season, representing spring–summer (wet) and fall (dry). In all of the studies, the minerals most consistently deficient in the majority of forages were P, Na, Cu, Se, and Zn. The minerals Ca, Mg and Co were borderline-to-deficient in some studies, depending on location, season, forage species and year. Minerals not deficient were K, Fe, and Mn. Molybdenum was not reported to be in excess for the present studies. However, a number of Florida studies have shown that excess Mo in high-pH soils (normally, organic soils) interferes with Cu metabolism, resulting in Cu deficiencies. Iodine, a mineral not analyzed, is believed to be adequate because there are no reports of goiter in Florida cattle.

Table 3 illustrates monthly mineral concentrations of bahiagrass forages over a 2-year period on a central Florida ranch (Espinoza et al., 1991a,b). There were monthly and yearly differences in mineral concentrations. Percentages of total forage samples with mineral concentrations below critical levels (in parenthesis) and suggestive of deficiency were as follows: Ca (.30%), 21%; Mg (.18%), 34%; K (.60%), 47%; Na (.06%), 89%; P (.25%), 85%; Co (.1ppm), 93%; Cu (8ppm), 98%; Fe (50ppm), 75%; Mn (40ppm), 41%; Mo (>6ppm), 0%; Se (.2ppm), 98%; and Zn (25ppm), 84%. From this study, once again the minerals most likely to be deficient and need supplementation were P, Na, Cu, Se, and Zn (and at this location also Co.) Iron was also relatively low.

Free-Choice Mineral Supplements

Free-Choice (Free-access) Mineral Supplementation

Voluntary consumption of individual minerals or mineral mixtures by animals is referred to as free-choice or free-access feeding. This practice of feeding minerals free-choice to ruminants has been used for many years to supply needed minerals, but is often based on the erroneous assumption that the animal knows which minerals are needed and how much of each mineral is required. Animals not consuming concentrates are less likely to receive an adequate mineral supply; free-choice minerals are much less palatable than concentrates and are often consumed irregularly. Intakes of free-choice mineral mixtures by grazing cattle are highly variable and not related to mineral requirements. Factors that affect the consumption of mineral mixtures have been listed by Cunha et al. (1964) and McDowell (1992), and include the following:

- Soil fertility and forage type consumed
- Season of year
- Available energy–protein supplements
- Individual requirements
- Salt content of drinking water
- Palatability of mineral mixture
- Availability of fresh mineral supplies
- Physical form of minerals

Typical Free-Choice Mixtures

Although it has been found that grazing cattle do not balance their mineral needs perfectly when consuming a free-choice mixture, there is usually no other practical way of supplying mineral needs under grazing conditions. As a low-cost insurance to provide adequate mineral nutrition, “complete” mineral supplements should be available free-choice to grazing cattle (Cunha et al., 1964). A complete mineral mixture usually includes salt, a low fluoride–phosphorus source, Ca, Co, Cu, Mn, I, Se, Fe, and Zn. Magnesium, K, S or additional elements can also be incorporated into a mineral supplement, or can be included at a later date as new information suggests a need. Many times I, Mn, and Fe can be excluded.

In excess, Ca, Cu, or Se can be more of a detriment to ruminant production than any benefit derived from providing a mineral supplement could offset. In Florida regions where high forage Mo predominates, 3 to 5 times the Cu content in mineral mixtures is needed to counteract Mo toxicosis (Cunha et al., 1964). As little as 3 ppm Mo has been shown to decrease Cu availability by 50%. Sulfur at 500 ppm can have the same effect. Thus, the exact level of Cu to use in counteracting Mo or S antagonism is a complex problem and should be worked out separately for each area. Table 4 lists the characteristics of a "good" (i.e., complete or "shotgun") mineral supplement (McDowell, 1992).

Some researchers feel there is no justification for the use of "shotgun" (complete) free-choice mineral mixtures that are designed to cover a wide range of environments and feeding regimens and have a built-in margin of safety. These people feel that "shotgun" mixtures are economically wasteful and can also be harmful. The authors disagree with this viewpoint on "shotgun" mixtures for cattle. There is little danger of toxicosis, or excessive cost in relation to the high probability of increased production rates for cattle, from offering cattle a complete "shotgun" mineral mixture free-choice, following the guidelines in Table 4. Copper and Se (added at recommended levels) would be the minerals of most concern for toxicosis. However, cattle, unlike to sheep, are much less sensitive to Cu toxicity; and inorganic forms of Se (e.g., sodium selenite) are not well utilized by livestock when administered in excess of the requirements. In conclusion, it is best to formulate free-choice mixtures on the basis of analyses or other available data. However, when no information on mineral status is known for a given region, a free-choice complete "shotgun" mineral supplement is definitely warranted as insurance against deficiencies.

Element Concentration in Mineral Mixture

The concentration of each element furnished by the mineral mixture can be compared to total requirements for that element to determine whether a significant amount is being furnished by the supplement. It is difficult to determine what constitutes a significant portion of the requirement for each mineral that should be supplied by the mixture, but it is generally believed the figure should be 25 to 50% for the trace elements. In zones known to have a trace mineral deficiency, 100% of the requirements for these elements should be provided. Table 5 illustrates the estimated trace mineral requirements and percentages of each element required in a beef cattle mixture to meet 25, 50, and 100% of the requirement. These figures are based on an estimated daily mineral consumption of 50g.

Free-Choice Mineral Supplement Evaluation

Problems with mineral supplementation programs have been summarized (McDowell, 1997) and include the following:

(1) insufficient chemical analyses and biological data to determine which minerals are required and in what quantities
(2) lack of mineral consumption data needed for formulating supplements
(3) inaccurate and(or) unreliable information on mineral ingredient labels
(4) supplements that contain inadequate amounts or imbalances
(5) standardized mineral mixtures that are inflexible for diverse ecological regions

(6) farmers not supplying mixtures as recommended by the manufacturer (e.g., mineral mixtures diluted 10:1 and 100:1 with additional salt)
(7) farmers not keeping minerals available to animals continually
(8) difficulties involved with transportation, storage, and cost of mineral supplements

Many of these problems are more related to tropical versus temperate regions because in temperate regions (more-developed countries) there is better quality control of products. However, some of the problems with temperate mineral mixes are related to inadequate quantities of Cu and Zn in mixtures, with some products low in P while others are still not providing Se. Responsible firms that manufacture and sell high-quality mineral supplements provide a great service to individual farmers. However, there are companies that are responsible for exaggerated advertising claims and some produce inferior products that are of little value or, worse, likely to be detrimental to animal production.

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Table 1. Macromineral composition (dry-matter basis) of various forages grown in Florida[a]

Forage	Florida Location	Sample No.	Ca (%)		P (%)		Mg (%)		K (%)		Na (%)		Source[b]
			Wet[c]	Dry[c]	Wet	Dry	Wet	Dry	Wet	Dry	Wet	Dry	
Bermudagrass–bahiagrass	Gainesville	24	.37	.30	.23	.20	.20	.20	1.09	.60	.05	.02	Salih et al., 1988a
Bermudagrass–bahiagrass	Gainesville	16	.30	—	.22	—	.22	—	1.43	—	.09	—	Salih et al., 1983
Bahiagrass	Gainesville	22	.32	—	.22	—	.20	—	1.80	—	.03	—	Rojas et al., 1987
Pangola grass	Gainesville	22	.36	—	.26	—	.21	—	2.00	—	.04	—	Rojas et al., 1987
Dwarf elephant grass[d]	Gainesville	25	.37	—	.40	—	.18	—	3.60	—	.05	—	Montalvo et al., 1987
Bermudagrass–bahiagrass	Gainesville	51	—	.40	—	.24	—	.14	—	1.0	—	.03	Merkel et al., 1990
Bahiagrass[e] (year 1)	central	252	.38	—	.17	—	.20	—	.68	—	.04	—	Espinoza et al., 1991a,b
Bahiagrass[e] (year 2)	central	252	.34	—	.19	—	.20	—	.74	—	.03	—	Espinoza et al., 1991a,b
Variable (mostly bahiagrass)	north–central	14	.42	—	—	—	.18	—	1.33	—	.06	—	McDowell et al., 1991
Bahiagrass	Gainesville	16	.42	.45	.18	.21	.24	.18	1.11	.31	.04	.02	Cuesta et al., 1993
Limpograss–maiden cane	southeast	7	.30	.30	.18	.10	.19	.14	1.03	.27	.18	.09	Kiatoko et al., 1982
Bahiagrass	southwest	11	.35	.46	.13	.10	.25	.15	.93	.47	.08	.07	Kiatoko et al., 1982
Bahiagrass	central	3	.40	.24	.18	.15	.21	.13	1.05	.56	.07	.08	Kiatoko et al., 1982
Bahiagrass	northwest	8	.27	.24	.18	.08	.19	.14	1.22	.62	.07	.10	Kiatoko et al., 1982
Bahiagrass	north–central	20	.29	.33	.24	.23	.38	.37	1.31	1.01	.03	.03	Tiffany, 1998

[a] Requirements or critical level is as follows (ppm): Ca, .30; P, .25; Mg, .20; K, .60; and Na, .06.

[b] References are available from authors.

[c] Wet and dry seasons represent spring–summer vs fall–winter, respectively.

[d] Samples collected from April through October

[e] Samples collected monthly throughout year

Table 2. Trace mineral composition (dry-matter basis) of various forages grown in Florida[a]

Forage	Florida Location	Sample No.	Cu[b]		Fe[b]		Mn[b]		Co[b]		Se[b]		Mo[b]		Zn[b]		Source[c]
			Wet[d]	Dry[d]	Wet	Dry	Wet	Dry	Wet	Dry	Wet	Dry	Wet	Dry	Wet	Dry	
Bermudagrass–bahiagrass	Gainesville	24	4.4	4.8	55	80	66	71	.13	.14	.04	.03	.20	.18	21	28	Salih et al., 1988b
Bermudagrass–bahiagrass	Gainesville	16	15	—	29	—	66	—	.12	—	.04	—	.20	—	19	—	Salih et al., 1983
Bahiagrass	Gainesville	22	5.1	—	—	—	22	—	.09	—	.08	—	.24	—	22	—	Rojas et al., 1987
Pangola grass	Gainesville	22	4.7	—	—	—	108	—	.07	—	.05	—	.44	—	25	—	Rojas et al., 1987
Dwarf elephant grass[e]	Gainesville	25	—	—	56	—	23	—	—	—	—	—	—	—	24	—	Montalvo et al., 1987
Bermudagrass–bahiagrass	Gainesville	51	—	4.2	—	95	—	123	—	.06	—	.05	—	.52	—	26	Merkel et al., 1990
Bahiagrass[f] (year 1)	central	252	3.0	—	43	—	55	—	.05	—	.07	—	.82	—	19	—	Espinoza et al., 1991a,b
Bahiagrass[f] (year 2)	central	252	3.3	—	45	—	52	—	.07	—	.07	—	.97	—	18	—	Espinoza et al., 1991a,b
Variable (mostly bahiagrass)	north–central	14	4.4	—	65	—	88	—	.19	—	.09	—	.49	—	29	—	McDowell et al., 1991
Bahiagrass	Gainesville	16	5.9	3.2	115	122	151	73	.06	.02	.05	.04	.28	.23	23	16	Cuesta et al., 1993
Limpograss–maiden cane	southeast	7	12.2	11	100	93	83	131	.11	.12	.08	.03	.86	1.16	30	30	Kiatoko et al., 1982
Bahiagrass	southwest	11	—	—	56	80	35	62	.09	.15	.07	.04	.22	.70	17	26	Kiatoko et al., 1982
Bahiagrass	central	3	—	—	71	128	15	61	.10	.26	.02	.13	.22	.20	17	20	Kiatoko et al., 1982
Bahiagrass	northwest	8	17.5	5.5	259	248	119	78	.12	.15	.06	.02	.24	.27	17	16	Kiatoko et al., 1982
Bahiagrass	north–central	20	6.0	4.4	48	52	74	93	.03	.03	.03	.04	.18	.25	24	18	Tiffany, 1998

[a] Requirements or critical level is as follows (ppm): Cu, 10; Fe, 30; Mn, 40; Co, .1; Se, .20; Mo, >6; and Zn, 30.

[b] Composition = ppm.

[c] References are available from authors.

[d] Wet and dry seasons represent spring–summer vs fall–winter, respectively.

[e] Samples collected from April through October

[f] Samples collected monthly throughout year

Table 3. Forage minerals of bahiagrass (dry-matter basis) as related to month and year in central Florida[a]

Element	Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Yearly Means
Ca, %	1	.40	.43	.42	.37	.44	.39	.33	.37	.33	.32	.33	.41	.38
	2	.45	.38	.34	.41	.41	.32	.26	.29	.25	.38	.40	.40	.34
Mg, %	1	.16	.19	.17	.16	.22	.21	.23	.29	.23	.20	.20	.18	.20
	2	.17	.12	.17	.17	.21	.13	.26	.24	.26	.17	.27	.26	.20
K, %	1	.40	.21	.45	.60	1.05	1.04	.79	.85	1.00	.53	.54	.75	.68
	2	.33	.41	1.28	.61	1.09	.66	1.15	.95	.74	.48	.50	.55	.74
Na, %	1	.05	.01	.02	.02	.03	.03	.04	.03	.02	.04	.03	.03	.04
	2	.02	.02	.04	.03	.05	.05	.04	.03	.04	.07	.05	.05	.03
P, %	1	.12	.12	.16	.19	.23	.18	.19	.16	.18	.18	.16	.16	.17
	2	.14	.16	.24	.15	.21	.19	.24	.22	.22	.18	.17	.18	.19
Co, ppm	1	.06	.04	.07	.06	.07	.03	.03	.02	.06	.04	.04	.07	.05
	2	.05	.06	.29	.04	.03	.04	.04	.04	.05	.06	.07	.08	.07
Cu, ppm	1	2.5	2.8	2.9	2.8	3.6	3.4	2.7	3.0	3.0	2.5	2.9	3.0	3.0
	2	2.4	2.2	4.7	1.7	4.2	3.8	4.2	2.9	2.4	2.4	4.2	4.1	3.3
Fe, ppm	1	49	36	62	51	49	38	44	40	38	32	36	46	43
	2	48	47	58	46	42	45	47	38	38	39	47	47	45
Mn, ppm	1	47	70	98	60	60	40	42	35	43	49	56	63	55
	2	76	76	76	57	39	31	39	23	32	50	66	65	52
Mo, ppm	1	1.4	1.4	1.3	.4	.6	.7	.7	.5	.7	.6	.8	.8	82
	2	1.1	.5	.4	.8	.5	.6	.7	.4	.3	.6	3.6	2.2	97
Se, ppm	1	.09	.09	.09	.07	.05	.04	.06	.05	.05	.07	.09	.06	.07
	2	.08	.08	.06	.11	.06	.07	.06	.04	.05	.06	.07	.07	.07
Zn, ppm	1	19	21	29	21	21	21	20	14	20	12	14	17	19
	2	18	15	26	13	22	24	20	15	15	17	11	17	18

[a] Means are based on 21 samples per month.

Table 4. Characteristics of an acceptable complete free-choice cattle mineral supplement[a]

1	Contains a minimum of 6 to 8% total P. In areas where forages are consistently lower than .20% P, mineral supplements in the 8 to 10% phosphorus range are preferred.
2	Has a calcium–phosphorus ratio not substantially over 2:1.
3	Provides a significant proportion (e.g., about 50%) of the trace mineral requirements for Co, Cu, I, Mn, Se and Zn.[a] In known regions known to be trace mineral deficient, 100% of specific trace minerals should be provided.
4	Includes high-quality mineral salts that provide the best biologically available forms of each mineral element, and avoids or minimally includes mineral salts containing toxic elements. (As an example, phosphates containing high F should be either avoided or formulated so that breeding cattle would receive no more than 30 to 50 ppm F in the total diet.) Fertilizer or untreated phosphates could be used to a limited extent for feedlot cattle.
5	Is sufficiently palatable to allow adequate consumption in relation to requirements.
6	Is backed by a reputable manufacturer with quality-control guarantees as to accuracy of mineral-supplement label.
7	Has an acceptable particle size that will allow adequate mixing without smaller-sized particles settling out.
8	Is formulated for the area involved, the level of animal productivity, the environment in which it will be fed (temperature, humidity, etc), and is as economical as possible in providing the mineral elements used.

[a] Iron should be included in temperate region mixtures, but often both Fe and Mn can be eliminated for acid soil regions. In certain areas where parasitism is a problem, Fe supplementation may be beneficial.

Table 5. Quantities of trace mineral supplements to meet 25%, 50%, and 100% of requirements[a,b]

Element	**Estimated maximum requirement (ppm)**	**Percentage of minerals in mixture**		
		25% of requirements	50% of requirements	100% of requirements
Cobalt	.1	.0005	.001	.002
Copper	10	.05	.10	.20
Iodine	.8	.004	.008	.016
Manganese	25	.125	.25	.50
Zinc	50	.25	.50	1.0
Iron	50	.25	.50	1.0
Selenium	.2	.001	.002	.004

[a] From McDowell (1997).

[b] This assumes an average consumption of 50 g/day of mineral mixture for cattle and 10 kg of total dry feed per animal daily.

NOTES: