Forage Analyses from Cow/Calf Herds in 23 States

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Forage Analyses from Cow/Calf Herds in 23 States[1]

Background:

Nutrition has significant impacts on both production costs and returned revenue. Inadequate nutrition (deficiencies and excesses) can impact animal health and biological efficiencies. Forages, either animal or mechanically harvested, constitute the core of the nutrition programs for cow/calf operations. Based on results from the National Animal Health Monitoring System's Beef '97 Study, only 9% of cow/calf operations evaluated the nutritional content of feeds used in 1996, and only 22% balanced rations on their operations.[2] From the 1994 Beef Cow-calf Health and Productivity Audit (CHAPA), data on 348 samples from 327 producers in 18 states were collected to look at selected nutritional contents of a variety of forage types. The current study was completed to add data on selected nutritional parameters and enlarge the forage data set.

Experimental Procedures:

In 1997, a stratified random sample of cow/calf producers from 23 states (Table 1) was selected to participate in a survey of management procedures and animal health. Producers having at least five beef cows that participated in the initial interview (n=1,190) were eligible to continue in the study by allowing more data to be collected and submitting a forage sample for analysis without cost to them. Additional samples could be submitted by producers at their expense. All samples were collected by state and federal veterinary personnel and mailed to Kansas State University.

These samples were dried to determine absolute dry matter content, then ground and submitted to a commercial laboratory (Peterson Laboratories Inc., Hutchinson, KS) where an aliquot of each sample was analyzed for crude protein, acid detergent fiber, calcium, phosphorus, aluminum, copper, iron, manganese, molybdenum, sulfur, and zinc. All analyses at the commercial laboratory were done utilizing conventional proximate analysis procedures for protein and ADF. Conventional laboratory procedures were used to determine calcium and phosphorus concentration, whereas a standard ICP analyzer system was used to validate the results for aluminum, copper, iron, manganese, molybdenum, sulfur, and zinc analysis. The balance of each forage sample was then forwarded to Oregon State University for determination of selenium and Vitamin E concentrations.

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[1] This report is a product of a Cooperative Agreement between Dr. Corah and the USDA:Animal and Plant Health Inspection Service:Veterinary Services, Centers for Epidemiology and Animal Health.

[2] Reports on these and other data are available from the USDA:APHIS:VS, Centers for Epidemiology and Animal Health at 555 S. Howes, Ft. Collins, CO 80521 or by calling (970) 490-8000. They are also available on the internet at www.aphis.usda.gov/vs/ceah/cahm.

A copy of all test results were entered into a data base and a summary of the results was returned to the producer through the federal and state veterinary personnel involved in the collection process. Personnel at Kansas State University evaluated each of the analyses, and deficiencies or potential toxicities, where present, were brought to the attention of the producers.

A total of 709 samples from 678 producers were analyzed and are reported here. A breakdown of sample numbers by region and state for the 23 cooperating states is shown in Table 1.

Table 1. Forage Samples Submitted from Cow/Calf Producers by State.

Region	Region total	State	Number Samples
Central	**95**	Illinois	32
		Iowa	29
		Missouri	34
Northcentral	**150**	Kansas	44
		Nebraska	43
		North Dakota	27
		South Dakota	36
Southcentral	**128**	Oklahoma	30
		Texas	98
Southeast	**185**	Alabama	32
		Arkansas	25
		Florida	4
		Georgia	28
		Kentucky	6
		Mississippi	17
		Tennessee	32
		Virginia	41
West	**151**	California	24
		Colorado	35
		Montana	28
		New Mexico	4
		Oregon	30
		Wyoming	30
	Total number of samples:		**709**

FORAGE CATEGORIES

For analysis purposes, the forages were combined into 11 categories as follows.

Alfalfa/Alfalfa Mix--This breakdown included 90 samples that were predominantly alfalfa and 106 samples that were classified as alfalfa mix that were predominantly alfalfa/grass mixes.

Brome/Brome Mix--Fifteen samples were clearly designated as brome and another 5 samples as brome mix.

Bermuda/Bermuda Mix--Ninety-two samples were designated as bermuda and 20 were designated as bermuda grass mix.

Fescue/Fescue Mix--This category included 28 samples designated as fescue and 45 as fescue mix.

Orchard/Orchard Grass -This category included 15 samples designated as orchard grass and 19 as orchard grass mix.

Sudan/Sudan x Sorghum--This classification included 49 of the forage samples coded with sorghum or sudan in their heading plus an additional 12 samples designated as sorghum/sudan mix. (Please note: Four sorghum silages were included under the Silage/Silage Mix category).

Cereal Forages--The designation of the 46 cereal forages included those classified as wheat, oats, barley, or other.

Native--The native section includes 38 samples coded either as native or prairie grasses.

Grass--The grass and native headings probably overlap extensively. Additionally, this category may overlap with some of the other categories due to the mixture of grasses and other grass/hay combinations. This grouping includes 70 samples.

Silage/Silage Mix--Of the 31 samples classified in this category, 23 samples were coded predominantly corn silage, 4 samples as sorghum silage, 2 milo silage, 1 oat silage, and 1 haylage.

Other--This classification includes 28 samples with the breakdown as follows: kosia & Russian thistle (1), clover (4), crested wheat (2), bean hay/straw (2), millet (8), timothy (3), crabgrass (3), peanut hay (2), pea straw (2), and soybean hay (1).

In addition to a descriptive summary of the proximate forage analyses by forage type, the samples were categorized as deficient, marginally deficient, or adequate for the copper, manganese, selenium, sulfur, and zinc. Further, samples were classified according to concentration of iron, molybdenum, and sulfur because of their potential antagonistic roles or effects on the bioavailability of copper. If not within the ideal range, samples were classified into either a marginal or high antagonistic likelihood. An additional classification was the Maximum Tolerable Concentration (MTC) for each element. Maximum Tolerable Concentration is defined as the dietary level when fed for a limited period that will not impair animal performance and should not produce unsafe residues in human food derived from the animal. These classifications are shown in Table 2.

Table 2. Classification of Trace Elements in Forage Relative to Their Abilities to Meet Either Dietary Requirements or Cause an Antagonistic Problem with Copper

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

			Antagonistic Level**		
Copper Antagonist	**Deficient**	**Ideal**	**Marginal**	**High**	**MTC***
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

Due to some antagonistic interrelationships among the trace elements, it is somewhat difficult to classify forages with regard to trace element status. For example, dietary copper requirements are affected by antagonists such as molybdenum, sulfur, iron, and other elements which decrease the bioavailability of the copper in the sample. This results in a requirement for a higher concentration of copper than reported in Table 2. 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.

RESULTS

Table 3. Results of Forage Analyses by Forage Category

ALFALFA/ALFALFA MIX

Dry Matter Nutrient Analysis

(Mean values ± S.E.)

No. Samples	Dry Matter(%)	Crude Protein(%)	ADF (%)	NEG (Mcal/lb)	NEM (Mcal/lb)	TDN (%)	Calcium (%)	Phosphorus (%)	Vit. E (IU/kg)
196	84.76±.36	14.96±.29	39.71±.42	.30±.01	.63±.01	57.79±.36	1.10±.03 (n=194)*	.24±.01	21.97±.76

Trace Elements

	Aluminum (ppm)	Copper (ppm)	Manganese (ppm)	Zinc (ppm)	Selenium (ppb)	Copper to Molybdenum Ratio (ppm)
Mean ± S.E.	151.54±8.77	10.50±.32	56.97+2.17	23.03±.50	376.64±35.73	11.27± .97
Classification						
> MTC*, %**	0	0	0	0	1.02	--
Adequate, %	--	41.84	74.49	13.78	54.59	66.84
Marginal, %	--	57.65	23.98	52.04	20.41	6.63
Deficient, %	--	0.51	1.53	34.18	23.98	26.53

Copper Antagonists

Element	Mean ± S.E.	% Ideal	Antagonistic Level % Marginal	% High	% >MTC**
Iron	210.07±13.15 ppm	64.80	26.02	8.67	1.02
Molybdenum	1.96±.12 ppm	29.59	54.08	16.33	5.61
Sulfur	0.23±.01 %	22.96	48.47	18.88	2.04

*In some cases, not all samples were available for determination of calcium content

**Maximum Tolerable Concentration (MTC) also included in % High Antagonistic level.

Note: Percentages may not add to 100% as samples deficient of the specified element were not included.

The mean proximate analysis results of a 15.0% crude protein and a 39.7% acid detergent fiber (ADF) would be consistent with alfalfa harvested in a fairly mature stage or reflects the fact that 54.1% were alfalfa/grass mixes. Zinc was deficient in 34.2% of samples and marginally deficient in 52.0% of samples with only 13.8% of samples adequate. The manganese content of the samples was adequate in 74.5% of samples. Although the majority of samples were adequate for selenium, 1.0% exceeded the MTC and 24.0% were deficient. Although less than 1% of samples were classified as deficient in copper, 57.7% were classified as marginally deficient. This percentage combined with a relatively high percentage of samples containing either marginal or high level copper antagonists (iron, molybdenum and sulfur) plus the copper to molybdenum ratio suggests that even more of the samples were effectively deficient or marginally deficient in available copper. In addition, over 5% of samples had molybdenum levels above its MTC, 1.0% of samples above the iron MTC, and 2.0% of samples above the sulfur MTC. Performance of animals fed these samples with values above the MTC would likely be compromised.

BROME

Dry Matter Nutrient Analysis

(Mean values ± S.E.)

No. Samples	Dry Matter(%)	Crude Protein(%)	ADF (%)	NEG (Mcal/lb)	NEM (Mcal/lb)	TDN (%)	Calcium (%)	Phosphorus (%)	Vit. E (IU/kg)
20	85.87±.92	9.35±.61	42.29±.64	0.27±.01	0.60±.01	55.49±.50	0.60±.07	0.20±.01	28.99± 2.72

Trace Elements

	Aluminum (ppm)	Copper (ppm)	Manganese (ppm)	Zinc (ppm)	Selenium (ppb)	Copper to Molybdenum Ratio (ppm)
Mean ± S.E.	115.22±67.45	9.53±.1.12	69.31±6.02	19.46±1.54	189.95± 39.55	12.54±3.25
Classification						
MTC*, %*	0	0	0	0	0	0
Adequate, %	--	25.00	85.00	5.00	30.00	80.00
Marginal, %	--	75.00	15.00	15.00	25.00	5.00
Deficient, %	--	0	0	80.00	45.00	15.00

Copper Antagonists

Element	Mean ± S.E.	% Ideal	Antagonistic Level % Marginal	Antagonistic Level % High	% >MTC*
Iron	155.78±20.91 ppm	50.00	35.00	0	0
Molybdenum	1.23±.17 ppm	50.00	45.00	5.00	0
Sulfur	0.15±.01 %	35.00	10.00	0	0

*Maximum Tolerable Concentration

Only 20 samples could be classified as brome in the data set. Values for average crude protein content and ADF were consistent with harvesting between midbloom to mature stage. Interpretation is difficult with the limited sample size . However, zinc was classified deficient in 80.0% of samples. Only 5.0% of samples were considered adequate for zinc. Copper was adequate in 25.0% of the samples but this again should be interpreted in view of the level of copper antagonists. Additionally, 70.0% of brome samples were deficient or only marginally deficient for selenium. No samples contained elemental concentrations greater than MTC.

BERMUDA

Dry Matter Nutrient Analysis

(Mean Values ± S.E.)

No. Samples	Dry Matter(%)	Crude Protein(%)	ADF (%)	NEG (Mcal/lb)	NEM (Mcal/lb)	TDN (%)	Calcium (%)	Phosphorus (%)	Vit. E (IU/kg)
112	83.86±.96	9.18±.24	40.41±.33	0.29±.01	0.62±.01	57.00±.26	.43± .02 (n=111)	0.22±.01	27.91± .1.60

Trace Elements

	Aluminum (ppm)	Copper (ppm)	Manganese (ppm)	Zinc (ppm)	Selenium (ppb)	Copper to Molybdenum Ratio (ppm)
Mean ± S.E.	182.30±67.21	10.59±.72	126.51±7.18	33.47±1.87	142.26± 14.96	39.22±5.03
Classification						
MTC*, %*	0.89	0	0	0	0	0
Adequate, %	--	35.71	92.86	43.75	19.64	94.64
Marginal, %	--	64.29	7.14	48.21	27.68	1.79
Deficient, %	--	0	0	8.04	52.68	3.57

Copper Antagonists

Element	Mean ± S.E.	% Ideal	Antagonistic Level: % Marginal	Antagonistic Level: % High	% >MTC*
Iron	165.22±36.96 ppm	83.04	10.71	2.68	0.89
Molybdenum	0.61±.09 ppm	82.14	15.18	2.68	1.79
Sulfur	0.27±.01 %	13.39	44.64	33.93	8.04

*Maximum Tolerable Concentration

The crude protein and ADF values for these samples indicate that, on average, the bermuda samples were harvested between the midbloom to mature stage of maturity. Zinc was deficient in only 8.0% of samples but was marginally deficient in another 48.0%. Although no samples were in the deficient range for copper, 64.3% of samples were marginally deficient. Only 13.4% of the samples were within the ideal range for sulfur, while the remaining samples were at levels classified as marginally or highly antagonistic for copper. Since additional intake of sulfur can occur in water as sulfate, water samples from the original locations of these samples should be evaluated when considering the potential for adverse health effects. A low percentage (13.4%) of samples had antagonistic levels of iron. The copper to molybdenum ratio was deficient in 3.6% of samples. In addition, 0.9%, 0.9%, 1.8%, and 8.0% of samples had aluminum, iron, molybdenum, and sulfur levels above their MTC levels. Regarding selenium, 80.4% of the samples were deficient or only marginally deficient, with only 19.6% considered adequate. Based on copper antagonist and selenium findings, animal performance may be compromised. On the positive side, 93% of the samples contained adequate levels of manganese.

FESCUE

Dry Matter Nutrient Analysis

(Mean values ± S.E.)

Number Samples	Dry Matter(%)	Crude Protein(%)	ADF (%)	NEG (Mcal/lb)	NEM (Mcal/lb)	TDN (%)	Calcium (%)	Phosphorus (%)	Vit. E (IU/kg)
73	82.50±1.55	9.80±.31	43.69±.52	0.26±.01	0.59±.01	54.43±.41	0.54± .03 (n=72)	0.26±.01	17.04± 1.07

Trace Elements

	Aluminum (ppm)	Copper (ppm)	Manganese (ppm)	Zinc (ppm)	Selenium (ppb)	Copper to Molybdenum Ratio (ppm)
Mean ± S.E.	112.82±12.28	9.26±.51	151.84±11.38	23.62±1.08	79.29± 6.31 (n=72)	17.13±1.91
Classification						
MTC*, %*	0	0	0	0	0	0
Adequate, %	--	26.03	97.26	15.07	4.11	80.82
Marginal, %	--	72.60	2.74	46.58	17.81	5.48
Deficient, %	--	1.37	0	38.36	78.08	13.70

Copper Antagonists

Element	Mean ± S.E.	% Ideal	Antagonistic Level % Marginal	Antagonistic Level % High	% >MTC*
Iron	153.83±21.65 ppm	82.19	6.85	5.48	1.37
Molybdenum	1.08±.10 ppm	49.32	46.58	4.11	0
Sulfur	0.19±.01 %	38.36	42.47	1.37	0

*Maximum Tolerable Concentration

A total of 73 fescue or fescue mix samples were evaluated. The crude protein content in these samples of 9.8% is representative of harvesting this type of forage in the mature stage. Nearly all the samples (97%) contained adequate levels of manganese, however, 38.4% of samples were classified as deficient in zinc. An additional 46.6% were only marginally deficient in zinc. Copper was classified as adequate in only 25% of samples and marginally deficient in another 72.6%. A substantial percentage of samples had either marginal or high copper antagonistic concentrations of iron, molybdenum, or sulfur. Iron was also above the MTC in 1.4% of the samples. In addition, the copper to molybdenum ratio was classified deficient in 13.7% of samples. An overwhelming majority of these samples (78.1%) were deficient in selenium. The combined effects of these observations suggest copper and selenium supplementation may be required when many of these forage types are being fed in order to avoid adverse effects on animal production or health.

ORCHARD/ORCHARD GRASS MIX

Dry Matter Nutrient Analysis

(Mean values ± S.E.)

No. Samples	Dry Matter(%)	Crude Protein(%)	ADF (%)	NEG (Mcal/lb)	NEM (Mcal/lb)	TDN (%)	Calcium (%)	Phosphorus (%)	Vit. E (IU/kg)
34	85.10±2.03	9.41±.71	43.42±.97	0.26±.01	0.59±.01	54.59±.76	0.50± .04	0.25±.01	25.22± 5.72

Trace Elements

	Aluminum (ppm)	Copper (ppm)	Manganese (ppm)	Zinc (ppm)	Selenium (ppb)	Copper to Molybdenum Ratio (ppm)
Mean ± S.E.	100.88±9.65	7.44±.42	121.46±12.26	24.13±2.02	100.38± 15.47	15.71±2.76
Classification						
MTC*, %*	0	0	0	0	0	0
Adequate, %	--	11.76	94.12	11.76	5.88	76.47
Marginal, %	--	82.35	5.88	44.12	26.47	8.82
Deficient, %	--	5.88	0	44.12	67.65	14.71

Copper Antagonists

Element	Mean ± S.E.	% Ideal	Antagonistic Level % Marginal	% High	% >MTC*
Iron	119.10±15.40 ppm	73.53	20.59	0	0
Molybdenum	1.50±.54 ppm	52.94	44.12	2.94	2.94
Sulfur	0.18±.01 %	44.12	17.65	8.82	0

*Maximum Tolerable Concentration

Only 34 samples were classified in the Orchard/Orchard Grass Mix category. The average crude protein concentration (9.4%) and ADF concentration (43.4%) suggest most samples were harvested in a reasonably late stage of maturity. Manganese was classified as adequate in 94.1% of samples. A high percentage (88.2%) of samples were either deficient or marginally deficient in zinc. Copper was classified as adequate in only 11.8% of samples. Molybdenum was classified as either marginal or high antagonistic potential in 47.1% of samples. The combined effects of low copper and high molybdenum resulted in deficient copper to molybdenum ratios in 14.71% of samples. Sulfur and iron concentrations are also potentially antagonistic to copper. Thus, the need for copper supplementation may be more than the copper concentration suggests. Close to 3% of the samples were above the MTC for molybdenum, and animal performance may be compromised. Again, the majority of the samples were deficient in selenium with only 5.9% considered adequate.

SUDAN

Dry Matter Nutrient Analysis

(Mean values ± S.E.)

No. Samples	Dry Matter(%)	Crude Protein(%)	ADF (%)	NEG (Mcal/lb)	NEM (Mcal/lb)	TDN (%)	Calcium (%)	Phosphorus (%)	Vit.E (IU/kg)
61	80.54±1.60	7.09± .32	43.95± .69	0.26±.01	0.58±.01	54.34± .54	0.49± .03	0.19±.01	19.44± 1.37

Trace Elements

	Aluminum (ppm)	Copper (ppm)	Manganese (ppm)	Zinc (ppm)	Selenium (ppb)	Copper to Molybdenum Ratio (ppm)
Mean ± S.E.	279.26± 39.13	12.00± .91	67.54± 4.56	25.64±1.49	165.89± 19.45	22.09±3.86
Classification						
MTC*, %*	4.92	0	0	0	0	0
Adequate, %	--	49.18	83.61	26.23	22.95	91.80
Marginal, %	--	49.18	16.39	42.62	45.90	1.64
Deficient, %	--	1.64	0	31.15	31.15	6.56

Copper Antagonists

Element	Mean ± S.E.	% Ideal	Antagonistic Level % Marginal	Antagonistic Level % High	% >MTC*
Iron	320.63± 41.26 ppm	50.82	24.59	24.59	6.56
Molybdenum	1.09±.12 ppm	49.18	44.26	6.56	0
Sulfur	0.12±.01 %	13.11	4.92	1.64	0

*Maximum Tolerable Concentration

The 61 sudan/sudan x sorghum/sorghum samples contained crude protein and ADF concentrations typical of harvesting at the fairly mature stage. Manganese was the only trace element where most of the samples (83.6%) were classified as having an adequate level. A substantial number of samples were deficient(31.2%) or marginally deficient (42.6%) in zinc. Although about one-half of the samples were classified as adequate for copper, the noticeable trend of high iron content (mean = 320.6 ppm) and high molybdenum resulted in approximately 50% of samples having either marginal or high copper antagonistic potential; 6.6% of samples had iron levels well above the MTC. Only 13.1% of samples had ideal levels of sulfur and another 6.6% of samples had copper antagonistic concentrations leaving 80% of samples potentially deficient in sulfur. Selenium concentrations were quite variable with almost one-third (31.2%) considered deficient and another 45.9% marginally deficient. Also, 4.9% of samples had aluminum levels above the MTC. The antagonistic effects of aluminum on iron and zinc absorption have been documented. Other potential antagonisms may exist but are not well documented.

CEREAL

Dry Matter Nutrient Analysis

(Mean values ± S.E.)

No. Samples	Dry Matter(%)	Crude Protein(%)	ADF (%)	NEG (Mcal/lb)	NEM (Mcal/lb)	TDN (%)	Calcium (%)	Phosphorus (%)	Vit. E (IU/kg)
46	83.31±2.36	8.92±.61	39.68±.98	0.30±.01	0.63±.01	57.61±.78	0.36± .02	0.22±.01	18.79± 4.65

Trace Elements

	Aluminum (ppm)	Copper (ppm)	Manganese (ppm)	Zinc (ppm)	Selenium (ppb)	Copper to Molybdenum Ratio (ppm)
Mean ± S.E.	168.34±31.57	8.27±.42	94.98±14.46	23.00±1.23	146.72± 30.83	23.42± 3.26
Classification						
MTC*, %*	2.17	0	0	0	0	0
Adequate, %	--	23.91	84.78	21.74	19.57	91.30
Marginal, %	--	76.09	13.04	32.61	28.26	0
Deficient, %	--	0	2.17	45.65	52.17	8.70

Copper Antagonists

Element	Mean ± S.E.	% Ideal	Antagonistic Level % Marginal	% High	% >MTC*
Iron	174.21±32.09 ppm	71.74	13.04	6.52	2.17
Molybdenum	1.01±.28 ppm	65.22	30.43	4.35	2.17
Sulfur	0.17±.01 %	39.13	21.74	2.17	0

*Maximum Tolerable Concentration

These 46 samples show an average proximate analysis typical of cereal-type forages. Manganese was adequate in 84.8% of samples. Zinc was adequate in only 21.7% of samples and deficient or marginally deficient in the balance of samples. The copper to molybdenum ratio was deficient in 8.7% of samples. This combined with the antagonistic concentrations of iron, molybdenum, and sulfur suggest the adequacy of copper concentrations in some of these samples is to be questioned. Copper concentrations were only marginally deficient in 76.1% of the samples. The majority of samples were deficient (52.2%) or marginally deficient (28.3%) in selenium with less than 20% adequate. Supplementation strategies need to be planned accordingly to an individual sample basis.

NATIVE GRASS

Dry Matter Nutrient Analysis

(Mean values ± S.E.)

No. Samples	Dry Matter(%)	Crude Protein(%)	ADF (%)	NEG (Mcal/lb)	NEM (Mcal/lb)	TDN (%)	Calcium (%)	Phosphorus (%)	Vit. E (IU/kg)
38	82.13±2.60	7.65±.66	42.76±.85	0.27±.01	0.60±.01	55.24±.65	0.53± .03	0.17±.02	48.87± 6.68

Trace Elements

	Aluminum (ppm)	Copper (ppm)	Manganese (ppm)	Zinc (ppm)	Selenium (ppb)	Copper to Molybdenum Ratio (ppm)
Mean ± S.E.	139.93±25.21	8.53±.58	117.25±18.63	24.30±1.56	163.39± 29.88	17.63±4.43
Classification						
MTC*, %*	0	0	0	0	0	0
Adequate, %	--	18.42	86.84	23.68	23.68	76.32
Marginal, %	--	81.58	13.16	39.47	36.84	2.63
Deficient, %	--	0	0	36.84	39.47	21.05

Copper Antagonists

Element	Mean ± S.E.	% Ideal	Antagonistic Level % Marginal	Antagonistic Level % High	% >MTC*
Iron	178.58±33.94 ppm	71.05	18.42	5.26	2.63
Molybdenum	1.24±.20 ppm	63.16	28.95	7.89	2.63
Sulfur	0.17±.01 %	21.05	23.68	7.89	2.63

*Maximum Tolerable Concentration

The 38 native grass samples contained an average crude protein content of 7.7% which is typical for native grass harvested in a relatively mature stage of growth. Manganese was adequate in a high percentage of samples (86.8%). Zinc and copper are of concern due to the high percentage classified as marginally deficient or deficient. In addition, a fairly high percentage of the samples contained enough iron, molybdenum, or sulfur to further affect the copper bioavailability. The copper to molybdenum ratio was classified deficient in 21.0% of samples. Thus, careful evaluation of the need for copper supplementation should be undertaken. Iron, molybdenum, and sulfur were above their MTC's in small percentages of samples. Selenium levels were variable with 39.5% of samples deficient and another 36.8% marginally deficient.

GRASS

Dry Matter Nutrient Analysis

(Mean values ± S.E.)

No. Samples	Dry Matter(%)	Crude Protein(%)	ADF (%)	NEG (Mcal/lb)	NEM (Mcal/lb)	TDN (%)	Calcium (%)	Phosphorus (%)	Vit. E (IU/kg)
70	80.54±2.02	8.87±.38	43.02±.55	0.27±.01	0.59±.01	55.01±.42	0.57± .03	0.21±.01	31.00± 3.73

Trace Elements

	Aluminum (ppm)	Copper (ppm)	Manganese (ppm)	Zinc (ppm)	Selenium (ppb)	Copper to Molybdenum Ratio (ppm)
Mean ± S.E.	115.96±12.72	9.96±.65	114.32±11.38	29.39±2.23	165.77±25.60	15.01±2.70
Classification						
MTC*, %*	0	0	0	0	0	0
Adequate, %	--	30.00	88.57	34.29	22.86	71.43
Marginal, %	--	70.00	11.43	30.00	28.57	8.57
Deficient, %	--	0	0	35.71	48.57	20.00

Copper Antagonists

Element	Mean ± S.E.	% Ideal	Antagonistic Level % Marginal	Antagonistic Level % High	% >MTC*
Iron	152.94±17.90 ppm	84.29	11.43	4.29	0
Molybdenum	1.68±.27 ppm	38.57	51.43	10.00	2.86
Sulfur	0.19±.01 %	34.29	31.43	7.14	0

*Maximum Tolerable Concentration

As was typical with the native grass, analyses suggest the average grass sample was harvested at a relatively mature stage based on the mean crude protein content of 9.0%. Manganese was again adequate in the vast majority of samples (88.6%) with zinc adequate in only 34.3% of samples. A high percentage of these samples contained sufficient concentrations of copper antagonist to adversely affect the bioavailability of copper. In addition, 20% of samples had a copper to molybdenum ratio classified as deficient. This was due, in part, to over 60% of samples having levels of molybdenum that could potentially be antagonistic to copper. Also, 2.9% had a molybdenum concentration greater than the MTC. Sulfur and iron concentrations were of concern relative to copper utilization in some samples as well. Additionally, 77.1% of samples were deficient or marginally deficient in selenium.

SILAGE/SILAGE GRASS

Dry Matter Nutrient Analysis
(Mean values ± S.E.)

No. Samples	Dry Matter(%)	Crude Protein(%)	ADF (%)	NEG (Mcal/lb)	NEM (Mcal/lb)	TDN (%)	Calcium (%)	Phosphorus (%)	Vit. E (IU/kg)
31	45.14±2.79	8.88±.57	32.61±1.54	0.37±.02	0.70±.02	63.22±1.22	0.52±.13	0.23±.01	15.07± 3.52

Trace Elements

	Aluminum (ppm)	Copper (ppm)	Manganese (ppm)	Zinc (ppm)	Selenium (ppb)	Copper to Molybdenum Ratio (ppm)
Mean ± S.E.	135.08±20.98	10.49±1.79	61.13±8.37	24.97±1.84	207.68± 28.41	26.88±6.76
Classification						
MTC*, %*	0	0	0	0	0	0
Adequate, %	--	22.58	74.19	22.58	45.16	80.65
Marginal, %	--	77.42	25.81	45.16	22.58	6.45
Deficient, %	--	0	0	32.26	32.26	12.90

Copper Antagonists

Element	Mean ± S.E.	% Ideal	Antagonistic Level % Marginal	Antagonistic Level % High	% >MTC*
Iron	252.12±36.72 ppm	61.29	19.35	19.35	0
Molybdenum	0.91±.15 ppm	64.52	35.48	0	0
Sulfur	0.14±.01 %	16.13	9.68	3.23	0

*Maximum Tolerable Concentration

The 31 silage/silage mix samples reflected proximate analysis values typical for ensiled roughages. Manganese was adequate in a lower percentage of samples than in other forage types but was still adequate in 74.2% of samples. Zinc was deficient in 32.3% and marginally deficient in 45.2% of samples. Thus, zinc was adequate in less than 23% of samples. Copper was classified as adequate in only 22.6% of samples. This finding, combined with 19.4% of samples with deficient or marginal copper to molybdenum ratios, suggests the need to consider supplementation for copper if these forages were fed alone. The iron and sulfur levels of many of the evaluated samples are also of concern relative to copper availability. Selenium levels were variable with 54.8% being deficient or marginally deficient. No samples were above the MTC for any element evaluated.

OTHER

Dry Matter Nutrient Analysis
(Mean values ± S.E.)

No. Samples	Dry Matter(%)	Crude Protein(%)	ADF (%)	NEG (Mcal/lb)	NEM (Mcal/lb)	TDN (%)	Calcium (%)	Phosphorus (%)	Vit. E (IU/kg)
28	86.25±.75	9.30±.56	43.19±1.07	0.27±.01	0.59±.01	54.88±.86	0.69± .07 n=27	0.18±.01	28.57± 3.70

Trace Elements

	Aluminum (ppm)	Copper (ppm)	Manganese (ppm)	Zinc (ppm)	Selenium (ppb)	Copper to Molybdenum Ratio (ppm)
Mean ± S.E.	278.07±58.23	10.51±1.37	93.70±14.36	23.10±1.69	241.00± 51.26 n=27	24.07±7.74
Classification						
MTC*, %*	7.14	0	0	0	0	0
Adequate, %	--	35.71	96.43	17.86	42.86	85.71
Marginal, %	--	64.29	3.57	39.29	17.86	3.57
Deficient, %	--	0	0	42.86	39.29	10.71

Copper Antagonists

Element	Mean ± S.E.	% Ideal	Antagonistic Level % Marginal	Antagonistic Level % High	%>MTC*
Iron	346.82±98.03 ppm	57.14	28.57	14.29	7.14
Molybdenum	1.10±.24 ppm	71.43	21.43	7.14	3.57
Sulfur	0.16±.01 %	28.57	25.00	3.57	0

*Maximum Tolerable Concentration

The Other category represents samples that did not fit into the specified forage catagories. Crude protein and ADF levels suggest most of these forages were fairly mature at the time of harvesting. With only 28 samples in this classification, meaningful interpretation is tenuous and probably should be made on a sample-by-sample basis within this classification. In general, zinc was deficient or marginally deficient in most samples, while manganese was adequate in 96.4% of samples. Copper levels were considered adequate in 35.7% of samples but the high iron, molybdenum, and sulfur cloud effective interpretation. Aluminum levels were very high overall (mean 278.1 ppm) in this group of samples. Animal performance may be affected if fed those samples that had concentrations of aluminum, iron, or molybdenum above the MTC. Selenium levels were quite variable with 57.15% either deficient or marginally deficient.

OVERALL SUMMARY

Table 3. The Trace Mineral Classification for the 709 Forage Samples

	Animal Requirement Level				Copper Antagonistic Level	
Trace Element	**Deficient(%)**	**Marginally Adequate(%)**	**Ideal or Adequate(%)**	**>MTC***	**Marginal(%)**	**High(%)**
Aluminum	--	--	--	0.99	---	---
Copper	0.71	66.01	33.29	0	---	---
Manganese	0.56	14.10	85.33	0	---	---
Zinc	33.29	43.72	22.99	0	---	---
Selenium	43.44	26.09	30.18	.28	---	---
Cu:Mo Ratio	15.66	4.80	79.55	---	---	---
Sulfur	6.06	22.00	25.53	1.97	33.57	12.83
Iron	2.82	---	70.52	1.69	18.62	8.04
Molybdenum	--	---	51.48	2.68	40.34	8.18

*Maximum Tolerable Concentration

SUMMARY AND IMPLICATIONS

Results of this NAHMS study from 23 states indicate the trace elements in forages of greatest concern from the deficiency standpoint are zinc, selenium, and copper. Zinc concentrations were either marginally deficient or deficient in 77.0% of samples. Similarly, selenium and copper concentrations were either marginally deficient or deficient in 69.5% and 66.7%, respectively, of the forages sampled. Only 23.0%, 30.2%, and 33.3% of samples contained adequate concentrations of zinc, selenium, and copper. The concentration of copper is further compromised by the relatively high percentages of samples with either marginal or high antagonistic concentrations of sulfur, iron, or molybdenum. In contrast, 85.3% of samples had adequate concentrations of manganese with only 0.6% of samples being deficient. Results of this study underscore the recommendation to periodically include an evaluation of trace minerals and their antagonists with routine evaluation of the nutrient content of forage samples.

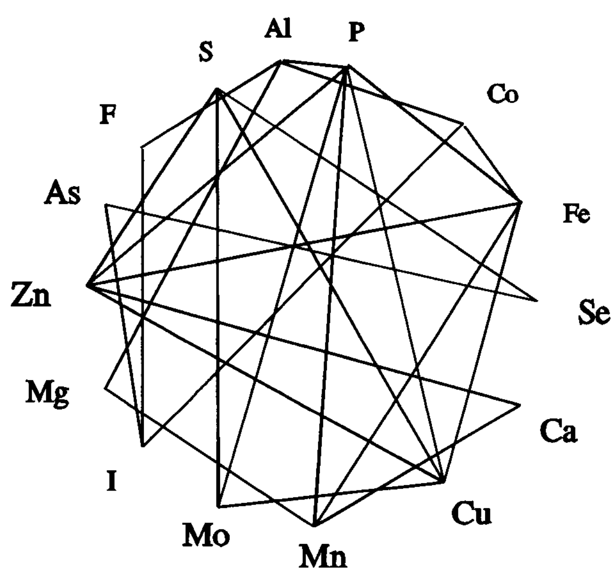
APPENDIX 1 --DISCUSSION OF SELECTED TRACE ELEMENTS AND RELATED NUTRIENTS

I. GENERAL

Seven trace elements are considered essential for beef cattle: cobalt, copper, iodine, iron, manganese, selenium, and zinc. Other trace elements, when consumed in sufficient quantities, may exert detrimental effects on livestock productivity through their interactive effects on the bioavailability and absorption of essential trace elements or may otherwise be toxic. This discussion will be focused only on those trace elements, the potential antagonists, and vitamin E that were included in the NAHMS Beef '97 Study. The direct effect of any single trace element is hard to evaluate due to the interactive effects of trace elements among themselves and with other nutrients.

Figure 1 may allow better visualization of the difficulty in evaluating a trace mineral problem. Please note the tremendous number of interactions. It is the complexity of these interactions that make it so difficult to evaluate the effects of elements on each other, particularly beyond the direct effect.

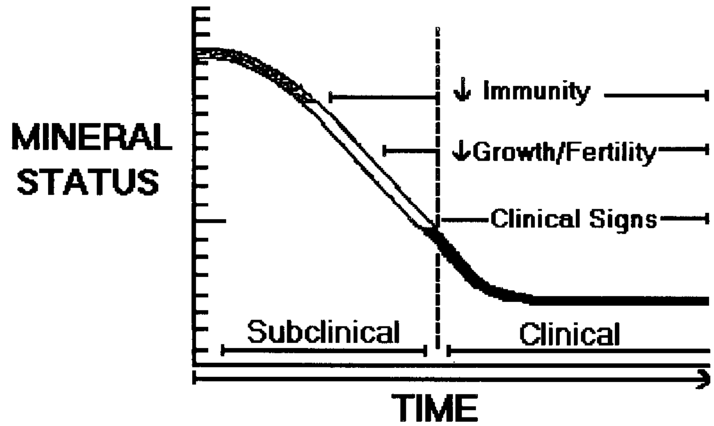
Figure 1. Overview of Selected Mineral and Trace Mineral Interactions



Adapted from: Greene, 1998, IRM Producer Education Seminars

Figure 2 shows the potential effects of trace mineral deficiencies on animal health and performance. Less than optimal levels of trace minerals may impact immune status, growth, and fertility long before overt signs of deficiency such as hair coat color and skeletal abnormalities are seen.

Figure 2. Effects of Trace Mineral Deficiencies on Immune Function and Productivity in Cows and Calves



Source: Wikse, 1992, Texas A&M University Beef Cattle Short Course

II. DIAGNOSIS OF TRACE MINERAL PROBLEMS

Evaluation involves herd history, dietary considerations and animal characteristics. Herd history is an essential component in evaluating trace element problems. It is recommended that this include both a personal interview with the owner/manager and an actual evaluation of production record information for at least 2 years prior to the current year. Special attention should be given to increased instances of disease, decreased animal performance measures (i.e., reproductive performance), and overt changes in the body condition and characteristics of the animals. This information should also include a detailed documentation of other risk factors of disease that may be noted on the particular operation.

A thorough evaluation of the protein and energy components of the diets should be made before considering mineral imbalances. A common concern about forage samples is animal selectivity. Given the choice, cattle will select forages of higher quality in terms of protein and sodium. However, this is not the case with the trace elements. Although availability of trace elements in a forage may vary, an assessment is considered essential in evaluating nutritional problems. Either clipped pasture or harvested forage samples may be analyzed. Random samples of representative forages need to be collected by appropriate methods to ensure that no soil contamination occurs. Samples should be stored in ziploc bags and kept cool until analyzed.

Serum, plasma or whole blood analysis, enzyme function tests, or liver tissue analysis have been used to assess trace mineral status in the animal. Analysis of serum for trace minerals is problematic. The majority of trace minerals in circulation are bound to various transport and enzymatic proteins that change dramatically with varying environmental, disease, and production states. However, blood levels may serve as a source of additional evidence to herd history in determining if a thorough trace mineral evaluation is necessary. A representative assortment of animals should be chosen that represent the herd average. Do not just evaluate the animals showing clinical problems. In addition, if blood is to be collected, it must be done properly to avoid contamination. The blood must be collected in tubes specifically designed for trace mineral evaluations. These tubes contain a siliconized stopper which prevents contamination due to leaching of elements from the rubber stoppers. In some cases, certain enzymes can be evaluated to estimate trace element status. This method offers a more direct representation of the trace mineral status than does serum or plasma evaluation but still may not be as conclusive as analysis of liver. Evaluation of liver trace mineral concentrations is the current method of choice. Obtaining liver biopsies has proven to be a safe and effective procedure in cattle of varying ages even when obtained multiple times throughout the year. Again a representative assortment of animals should be selected. Thorough consideration should be given to animal preparation and restraint, contamination factors, and sample storage.

Serum, liver biopsy, and forage samples should be sent to laboratories using inter-coupled plasma (ICP) mineral analysis technology. This technology is similar to the traditional atomic absorption spectroscopy but allows for a better controlled and highly sensitive evaluation of many minerals within each sample. Reputable laboratories usually have well established internal controls to validate results. It is generally recommended that evaluations include not only those elements of concern but also potential antagonists.

III. SELECTED MINERALS EVALUATED IN BEEF '97

A. ALUMINUM

General importance. Aluminum is not an essential trace element. It is, however, the third most abundant mineral in the earth's crust. Due to its abundance, aluminum commonly occurs in feed and the environment of animals. Aluminum is usually present at low concentrations in water but can increase with decreasing pH as is common in industrial waste discharge and mine leachate. Early work suggested that the ruminant gastrointestinal (GI) tract provided an effective barrier against aluminum, but later work has shown that aluminum absorption does occur in ruminants. Aluminum can enter the body from plant or soil ingestion, feed and water contamination, or as a planned additive in some selected feed supplements to alter metabolism or absorption of other minerals.

Toxicity. Ruminants are less susceptible than monogastrics to the toxic effects of aluminum. Therefore, it is not considered a major toxicant in cattle. High levels of aluminum have been shown to decrease feed intake and cause GI irritation. Presumably, the feed intake was associated with decreased palatability. The major effect that aluminum exerts is through interactions with other minerals and trace minerals, not necessarily as a direct effect. Aluminum will decrease fluoride uptake and may be of some benefit in the treatment of fluorosis. High levels of aluminum have been shown to react with both fluoride and phophorus to form insoluble, nonabsorbable complexes. Thus, the effects on animal performance are likely associated with the negative effects of low phosphorus. These affects can be overcome by increasing phosphorus intake. However, phosphorus metabolism is further affected by absorbed aluminum. Little to no effect has been reported on calcium absorption and metabolism, but high levels of aluminum have been implicated as a potential cause of grass tetany indicating an effect on magnesium. This was primarily linked to ingestion of high levels of aluminum from the soil. Aluminum does not decrease calcium or magnesium absorption but may affect retention. Effects of aluminum on other minerals are not well documented. The intestinal absorption and liver concentrations of both zinc and iron increase with high levels of aluminum. Other evidence suggests that the potential toxic effects of aluminum are increased by deficiencies of iron, copper, magnesium, and zinc. The implication of this information is that interactions do occur. The significance of these interactions need to be further evaluated.

Effects of Excess Aluminum Intake	
Decreased absorption or availability	Increased absorption or availability
Flouride	Iron
Magnesium	Zinc
Phosphorus	

B. COPPER

General importance. Copper (Cu) is involved in numerous physiological functions such as hemoglobin formation, iron absorption and mobilization and connective tissue metabolism--usually via copper's involvement in enzyme functions.

Deficiency. One of the major effects of copper deficiency may well be its effect on enzyme systems reducing productivity via alteration of enzymatic activity in the body. One of the less well documented effects of copper deficiency may be its impact on immune function. This may in fact represent copper deficiency's greatest economic consequence on the cattle industry. In instances of copper deficiency, it appears that the immune system is altered in animals making them more susceptible to a variety of diseases. The incidence of scours has increased in calves born to copper deficient dams. Documentation has shown that abomasal ulcers shortly after birth can be related to a copper deficiency in the calves. Other studies have reported increased respiratory problems in copper deficient calves. The mechanism of how the immune system is affected is being studied intensively at a number of locations. In at least one study, copper deficiency reduced the available copper for tissue and enzyme activity and resulted in animals having decreased neutrophil function.

A number of other research studies have clearly documented that copper deficiency can have an effect on fertility. This has been evidenced by a reduction in first service conception rates, embryonic survival (in situations of embryo transfer) and in overall pregnancy rates. Some studies have reported the effect on fertility to be from a very limited to a very pronounced decrease while others have reported little to no impact on fertility even where copper deficiency has been documented. Exactly how does copper alter reproductive function in animals? Good evidence exists that the reproductive effects of copper deficiency may be more associated with the negative effects of excesses of other nutrients such as molybdenum, iron, and sulfur on copper availability than actual copper deficiency (see iron, molybdenum, and sulfur). In addition to its effect on fertility, research has shown that there may be an alteration in normal estrous cyclicity. Specifically, cows may show normal estrus behavior, but in situations where a severe copper deficiency exists, ovulation does not occur. Subsequently, there is a retardation of future estrous cycles. In addition, there is evidence that copper deficiency may cause an alteration in semen quality in males, particularly in young developing bulls.

The clinical symptoms of a copper deficiency are extremely varied and occur more often in the younger animals. The enzyme, polyphenyl oxidase, affects the conversion of L-tyrosine to melanin, and often manifests as a change in the color of hair coat. This may show simply as a lightening of the hair coat in black or red animals or as a reddish tinge in the case of black animals. This generally appears behind the shoulder and on the lower parts of the body. Another feature is graying of the hair in black animals. On occasion, a copper deficiency may appear as graying of the hair around the eyes creating a "ring"; a common description is "spectacle eye." In general, a "rough" hair coat is a common, though non-specific, deficiency symptom. Other symptoms include anemia and abnormal bone and ligament development of calves, which may lead to an inability to walk or becoming more susceptible to foot and leg injuries. On occasion, growth rate of animals can be negatively affected.

Diagnosis. Diagnosis of any trace element deficiency often needs to be based on a number of factors which can include general clinical symptoms as previously described, data from blood or liver analysis, or information from a forage analysis. If any of the possible clinical symptoms appear, one of the early steps should be analysis of forage for copper levels. When this analysis is made, it's important to also analyze for the established copper antagonists of molybdenum, sulfur, and iron.

Table 1. Effect of Dietary Mo and Fe on Liver Copper in Growing Heifers

Week	Control*	Fe 500 ppm	Mo 5 ppm
0	128.7	134	127.4
8	48.9	16.3	19.5
16	31.3	5.6	4.8

*Fed basal diet only (Cu=4 ppm)
Source: Phillippo et al., 1987

Table 1 illustrates that high levels of molybdenum or iron reduce the level of copper in the liver. Both excessive iron and molybdenum resulted in more rapid depletion of liver copper than one would expect to occur even when feeding a copper deficient diet. When forage samples contain less than 10 ppm (mg/kg) copper, they are marginally deficient. This is especially a problem when molybdenum levels are in excess of 1-3 ppm, or when the copper to molybdenum ratio falls below 4.5:1. In some situations, copper:molybdenum ratios of 1:5 have been reported. Similar effects on copper have been observed when sulfur levels are greater than 0.3%, particularly in combination with high molybdenum levels. The combined effects of excessive iron, molybdenum, and sulfur occur, but are much harder to document. When liver biopsies are taken, concentrations below 75-90 ppm (on a dry matter basis) are considered deficient. Serum samples below .65 ppm indicate a potential deficiency may exist.

Toxicity. When concentrations of copper in the diet exceed 200-800 ppm in cattle, or 115 ppm in calves, a potentially toxic situation may result. Toxicity may occur as a result of excessive supplementation of copper or agricultural or industrial contamination of feedstuffs. The liver accumulates large stores before toxicity occurs. When large amounts of copper are released from the liver, severe hemolysis occurs which could lead to a hemolytic crisis and death. The animal will have an increased respiratory rate and have the characteristic jaundice appearance of the mucus membranes and whites of the eyes.

C. IRON

General importance. Iron is one of the most abundant trace elements and essential for all plants and animals. It is an essential component of many oxidation/reduction reactions and is required for hemoglobin, myoglobin, cytochromes, and other enzyme systems.

Deficiency. Reduced growth, anorexia, and anemia is associated with a deficiency of iron. Unless there is blood loss from lacerations or severe parasite infection, deficiencies are rare due to the abundance of iron in most feedstuffs. Generally iron content is high in forages, and iron is a common contaminant of phosphorus supplements. Some studies have shown a positive correlation between serum iron, manganese, copper, and zinc with reproductive performance. There is a high degree of variability in the bioavailability of iron among supplemental iron sources. Contamination of feedstuffs with soil will result in artificially high levels of iron in the sample. Iron from soil contamination is unavailable to the animal. Iron oxide is often used for aesthetic quality (color) in many mineral supplements but is very unavailable to the animal. In addition, ferrous forms of iron are more bioavailable than ferric forms. Ruminants also appear to be able to regulate the rate of absorption of iron at the level of intestinal epithelium.

Toxicity. Toxic effects of high iron intake include decreased weight gains as a result of decreased feed intake and efficiency. This tendency has been noticed with iron levels as low as 500 ppm. Cattle can be exposed to high levels of iron in water as well as forages. Some water sources have been found to contain as much as 180 ppm iron but normally contain less than 1 ppm. Irrigation water with 17 ppm iron has been associated with forage levels as high as 9980 ppm. Extremely high levels of iron will result in decreased productivity, weight loss, and a dark-colored, frothy, maloderous feces.

High dietary iron will decrease absorption of phosphorus and visa versa. Increases in iron and phosphorus reportedly decrease tissue concentrations of copper and zinc. High dietary iron also decreases kidney concentrations of magnesium. Iron absorption has been enhanced by increased consumption of aluminum, ascorbic acid, vitamin E, several amino acids, and certain sugars. High dietary iron (>400 ppm) will severely deplete copper stores and will also negatively affect selenium absorption. These interactive effects could result in clinical signs of deficiencies consistent with the affected trace minerals.

D. MANGANESE

General importance. Considerable attention in the livestock industry is focused on trace element deficiencies such as copper, selenium, zinc and other elements. One trace element that may have considerably more influence on animal health and productivity than previously realized is manganese. Manganese is nutritionally essential to both plants and animals and, unfortunately, is very poorly utilized from the diet by animals with evidence that only 14-18 percent of ingested manganese is actually absorbed. As with copper, manganese probably exerts its greatest influence on the animal via its incorporation into enzyme systems. Research evidence exists that manganese deficiencies can result in suppression of conception rates and delayed estrus in both postpartum females and young prepuberal heifers. In addition, there is excellent evidence that manganese deficiency will cause abortions in animals and deformed calves at birth. There is evidence that calves, at birth, will "knuckle over" at the fetlock.

Other symptoms reported include poor calf growth, loss of hair color in both calves and cows, and an increase in the incidence of cystic ovaries.

The mode of action by which manganese causes this deficiency is not clear other than it appears to be exerting these influences via enzyme systems in which it may be an essential cofactor. There is strong evidence, for example, that the manganese content of ovaries in normal cows was considerably higher than in those with high incidences of cystic ovaries. There is further evidence that manganese alters the synthesis of gonadal steroids such as estrogen and progesterone in the female. Part of this explanation relates to the role of manganese in altering ovarian luteal metabolism.

Unlike copper, iron, selenium, and zinc, there is no clear evidence at this time that manganese has a direct effect on immune function.

Diagnosis. Herd histories are suggestive but not definitive of manganese deficiency. One of the most effective methods of diagnoses of a manganese deficiency is simply a determination of the manganese content in the diet or forage being fed. A diet is considered deficient if less than 20-40 ppm manganese is present. Blood manganese below .005 ppm and liver manganese below 9-15 ppm on a dry basis can also be useful indicators of a manganese deficiency.

Toxicity. Unlike a number of the other trace elements, excessive levels of manganese in the diet generally are not toxic.

E. <u>MOLYBDENUM</u>

General importance. Molybdenum is a constituent of xanthine oxidase and other enzymes but not considered an essential trace element. Under natural conditions, no deficiencies have been reported. Potential sources of molybdenum include air, water, soil, forages, and feed supplements. Emissions from industrial complexes can contribute to soil and plant concentrations.

Toxicity. Molybdenum toxicosis may occur acutely, particularly in young calves and lactating cows, if dietary levels are equal to or greater than 20 ppm. This results in a severe diarrhea and the development of a dry haircoat with achromotrichia (lack of color). Chronic molybdenum toxicosis most commonly manifests itself as a copper deficiency. This chronic toxicosis can result in decreased growth, anemia, bone disorders, hair color changes, GI disorders, cardiovascular effects, and decreased reproduction. Molybdenum, sulfur, and copper have a complex interrelationship. Molybdenum and sulfur in the rumen combine to form thiomolybdates which combine with copper and form insoluble complexes and are poorly absorbed. In addition, some thiomolybdates can be absorbed and combine with absorbed copper and decrease its bioavailability. This interelationship has led to the development of a copper to molybdenum ratio that is considered adequate if it is between 4.5 to 10:1. Ratios above 10:1 will increase the risk of copper toxicosis, particularly in sheep.

Some reproductive effects of excess molybdenum have been identified. In at least one study, dietary inclusion of molybdenum delayed puberty in yearling beef heifers by 8-12 weeks. Dietary molybdenum also reduced conception rates from 68%, in cows with no molybdenum included in the diet, to 22% when molybdenum was included in the diet. Additionally, failure of cattle to ovulate may be related to molybdenum interference rather than copper deficiency. Specifically, the mechanism by which molybdenum inhibits ovulation is not clearly known. In the studies where puberty was delayed in heifers, the secretion of luteinizing hormone (LH) was altered; the pulsatile release of LH was not observed, and there was a lower basal level of LH secretion. Further, their studies showed that this altered LH release pattern may have been related to ovarian estradiol production. When estradiol was supplemented, normal LH secretion occurred and the animals did not exhibit altered ovarian function.

F. SELENIUM/VITAMIN E

General importance. Selenium, an important trace element, can be at both deficient and toxic concentrations in many areas of the U.S., even within the same state. Any discussion of selenium needs to also include vitamin E because of their interrelated functions. Although vitamin E will not be discussed to any extent in this appendix, there is excellent evidence that the role of vitamin E in beef cow diets needs to be reevaluated, and it is likely that in the future we will be using higher levels of vitamin E supplementation in a beef cow diet.

Deficiency. Selenium and/or vitamin E deficiency has been associated with nutritional myodegeneration or white muscle disease. White muscle disease typically affects the skeletal and heart muscle of young calves and occasionally in yearling cattle. It can be expected to affect those calves with the greatest demands for growth and production. Appetite and growth are decreased. Calves appear stiff and weak at birth or develop this after birth. Selenium deficiency has also been associated with decreased immune sytem function in animals making them considerably more susceptible to disease problems. The result is an increased death loss from scours and respiratory disease. In addition, animals may display excessive teeth grinding, muscle tremors, constant weight shifting, and difficulty in rising. Skeletal deformities like arched back may exist.

In addition, reproduction in both male and female cattle will be affected. One manner in which a selenium deficiency can affect reproduction in a cow herd is an increase in the incidence of early embryonic death and retained placentas. Selenium deficiency has also been associated with an increased incidence of cystic ovaries and an increased incidence of silent heat. The mode of action under which selenium may affect reproductive function is not clearly defined. It appears to function through its effect on the metabolism of hydrogen peroxide which may alter the synthesis of prostaglandin or its derivatives. This effect could then be associated with its impact on a number of reproductive parameters.

Diagnosis. One of the most effective ways of determining selenium status is a liver analysis. Liver levels of .8-1.0 ppm on wet weight basis are considered to be adequate, and levels below .2 ppm are considered to be deficient. Another method for determining selenium status is erythrocyte glutathione peroxidase; it is especially helpful in suspected cases of long-term selenium deficiency. As a general indicator of potential selenium deficiencies, whole blood samples can be utilized. Concentrations of with .05 ppm and below are considered to be deficient

Toxicity. Unfortunately, selenium is much like copper in that it can be both toxic and deficient with variability occurring even within small geographical areas. Diets containing over 80 ppm are considered to be toxic. Excessive selenium (selenosis) can occur with ingestion of selenium concentrating plants or for iatrogenic reasons. Clinicial signs are dependent on whether it is acute or chronic. Chronic selenosis typically is associated with lameness, abnormal growth of the hoof wall including sluffing of hoof, hair loss, and weight loss. Affected animals will usually show a degree of impaired vision or blindness. Acute toxicity is associated with respiratory distress, diarhea, loss of balance, and death.

G. SULFUR

General importance. Sulfur is considered an essential macromineral for cattle. It is a component of methionine, cysteine, and cystine plus thiamin and biotin. It is also a component of many other organic compounds and assists in certain detoxification functions of the body. Ruminal microorganisms are capable of synthesizing all sulfur containing compounds from inorganic sulfur.

Deficiency. Decreased dietary sulfur will lead to decreased rumenal microbial numbers and protein synthesis. This results in decreased feed intake, digestibility, and reduced growth rate. Severe deficiency results in weight loss, emaciation, excess salivation, and death. Marginal deficiency of sulfur on sorghum, sorghum x sudan, or corn silages are not uncommon. In addition, the sulfur requirement of ruminants grazing sorghum x sudan may be increased due to the concentration of cyanogenic glucoside found in most sorghum forages. Sulfur plays a role in the detoxification of cyanogenic glucoside.

Toxicity. The maximum tolerable concentration of sulfur has been set at 0.40% by the National Research Council (NRC, 1996). Levels above this can decrease feed intake and growth rate. Excessively high levels can lead to restlessness, muscle twitching, and diarrhea. Ultimately death can result. Polioencephalomalacia has also been associated with high sulfur intake. Most of these situations have been due to water with a high concentration of sulfate, but in some cases, forage or other feed ingredients high in sulfur can make a significant contribution. Sulfur also reduces copper absoption, both by the formation of copper sulfide in the gut and its role in the formation of thiomolybdate complexes. Both effectively reduce copper availability. Levels as low as 0.25% of sulfur in combination with molybdenum may form these complexes.

H. ZINC

General importance. Zinc, as with all of trace elements, is actively involved in enzyme function which plays a role in immune function and reproduction.

Deficiency. There is excellent evidence that zinc deficiency results in decreased immune function, particularly in stressed cattle. A good example may be newly arrived, recently weaned stocker or feedlot calves. The deficiency may be the result of decreased intake as well as an actual increase in dietary requirement. Nevertheless, this results in a higher dietary requirement in stressed animals for adequate disease prevention. Increased supplementation has been associated with decreased death losses and increased productivity of the stocker/feeder cattle.

The role of zinc deficiency on reproductive function appears to be more pronounced on the male side than on the female side. Evidence exists in research studies that zinc deficiency in the bull causes impaired fertility, possibly associated with an alteration in the late stage spermatozoa formation. This impairment of male infertility appears to be associated with the role of zinc as an activator of enzymes involved in the steroidogenesis process which results in the secretion of testosterone and related hormones.

In the female, there is some evidence of a decrease in fertility and, for some, indication of abnormal estrous cyclicity.

Diagnosis. As with other trace elements, blood can give some indication of a deficiency, however, care needs to be taken in interrupting serum levels. A more accurate determination can be made through either analysis of liver biopsies or forages. Liver tissue samples testing below 80-100 ppm (on a dry matter basis) are considered marginal or deficient. Dietary levels have been set at 30-40 ppm with levels as high as 75-100 ppm recommended during periods of stress.

Toxicity--Evidence of zinc toxicity in adult ruminants is relatively uncommon. However, there has been evidence that animals receiving above 500 ppm can show toxic effects.

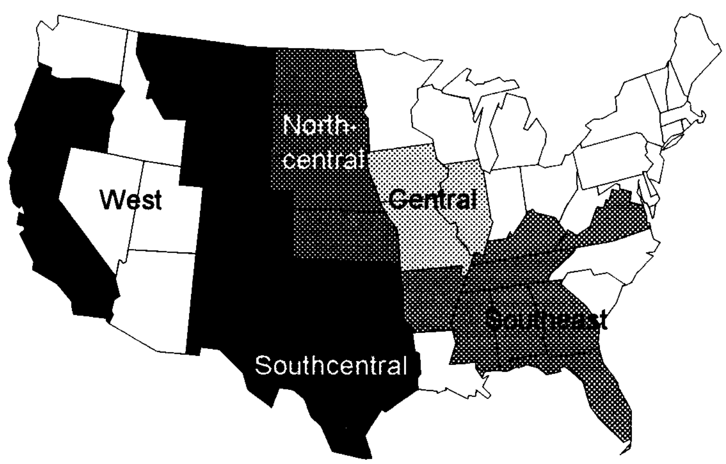
APPENDIX 2 -- Nutrient Analysis By Region

The following is a breakdown of the nutrient contents of various forage types by region.

SUMMARY OF DATA

As a general summary, samples collected in the southeastern part of the United States generally tended to have higher concentrations of most trace elements, except selenium, which was lower than in any of the other regions. Copper, zinc, and manganese concentrations tended to be higher in the Southeast region, and concentrations of antagonists, such as molybdenum and iron, tended to be lower. The reverse was present in the Northcentral and Central regions where fairly high levels of molybdenum and iron were often present. There was a tendency for selenium levels to be considerably higher in these regions, particularly the Northcentral region.

Beef '97 Forage Analysis Regions



NUTRIENT ANALYSIS BY REGION

Region	Forage Type	Number Samples	TDN (%)	Crude Protein, % DM	ADF % DM	Ca % DM	P % DM	Sulfur % DM	Vit. E (IU/kg)	Al ppm	Iron ppm	Mn ppm	Se ppb	Zinc ppm	Copper ppm	Mo ppm	Cu:Mo Ratio
Central	Alfalfa	38	57.04	15.12	41.73	1.00	0.30	0.20	17.19	128.07	220.28	74.20	166.34	27.43	10.80	1.41	17.29
	Fescue	19	54.29	10.43	43.91	0.68	0.26	0.18	16.05	79.65	108.21	122.16	98.21	22.54	10.15	1.40	11.75
	Grass	11	54.65	10.40	43.36	0.66	0.24	0.17	22.28	72.85	98.59	80.89	82.82	19.46	9.77	1.52	7.74
Northcentral	Alfalfa	77	56.48	14.92	41.04	n=76 1.16	0.22	0.22	17.99	174.22	222.98	55.56	621.53	22.55	10.46	2.39	8.89
	Sudan	16	54.35	7.14	43.74	0.41	0.20	0.11	17.37	262.40	300.32	66.43	181.06	26.18	9.39	1.03	20.48
	Silage	19	60.72	9.27	35.85	0.49	0.22	0.14	16.57	138.52	233.17	72.05	253.05	23.60	8.92	0.96	16.78
Southcentral	Bermuda	55	56.76	8.47	40.73	0.47	0.19	0.25	30.04	238.90	181.73	97.42	150.15	29.26	9.23	0.50	33.32
	Sudan	32	54.12	7.02	44.30	0.54	0.17	0.11	20.33	243.27	246.85	64.27	179.91	24.38	13.10	1.19	19.71
	Cereal	12	54.95	8.27	42.97	0.31	0.18	0.15	13.62	234.38	160.00	79.97	140.83	20.15	9.91	0.74	25.45
Southeast	Bermuda	56	57.21	9.80	40.13	n=55 0.39	0.26	0.28	25.56	126.15	145.34	153.17	136.25	37.51	11.86	0.68	45.64
	Fescue	47	54.19	9.82	43.98	n=46 0.51	0.27	0.19	17.57	122.49	156.85	149.30	n=46 74.15	23.94	9.30	1.03	16.81
	Grass	21	55.00	9.76	43.02	0.59	0.27	0.21	31.28	137.09	192.43	166.82	93.52	42.92	11.38	0.95	24.90
	Orchard	28	53.90	8.52	44.31	0.44	0.23	0.17	18.79	97.67	111.92	134.00	80.04	22.34	6.92	0.89	17.55
West	Alfalfa	67	59.40	14.84	37.46	n=66 1.12	0.23	0.26	28.48	140.09	191.11	44.88	239.30	21.38	10.37	1.94	9.97
	Cereal	19	59.67	8.45	37.18	0.39	0.23	0.17	15.10	107.44	144.51	89.71	193.11	22.47	7.57	1.51	19.33
	Native	13	58.07	10.00	39.03	0.60	0.22	0.21	50.08	194.24	260.04	88.68	212.69	18.78	8.39	2.12	6.08
	Grass	21	56.23	7.93	41.33	0.52	0.18	0.17	26.50	109.98	145.60	107.79	243.48	22.46	9.72	2.79	10.32

ADF=Acid Detergent Fiber; Al=Aluminum; Ca=Calcium; Cu=Copper; DM=Dry Matter; Mo=Molybdenum; Mn=Manganese; P= Phosphorus; Se=Selenium

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