SYMPOSIUM: NEW CONCEPTS AND DEVELOPMENTS IN TRACE ELEMENT NUTRITION

Variability in Mineral and Trace Element Content of Dairy Cattle Feeds

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ABSTRACT

Trace element content of feeds is extremely variable compared to total digestible nutrients or protein. Differences are wide between low and high values for many trace elements within a given type of feed. Coefficients of variation for forages range from 42 to 100%. Summary data are given for both major and trace elements. Problems in supplementation are discussed. Amounts for some elements are skewed with relatively few samples around the mean and over 60% below the mean. Suggested mineral allowances for dairy cows are listed. Under current supplementation, zinc is the trace element most likely to be limiting and manganese the least likely. Iron, copper, cobalt, and iodine may be limiting in some cases. Needs of research and applied nutrition are presented.

INTRODUCTION

Nutritionists have been concerned for years with the TDN (total digestible nutrients) or energy and protein contents of items used in feeding dairy cattle. To a lesser extent, there has been concern for amounts of calcium and phosphorus. However, too little attention has been paid to other elements, particularly trace elements. Often trace mineral concerns stop with the recommendation to use a commercial product that has been trace mineralized. Due to the extreme variability among feeds as well as other factors, good trace element nutrition does not come this easy. I hope this presentation will demonstrate the great variation in trace element content which may occur. In addition, summary data on mineral analysis for various feeds will be provided and practical considerations in trace mineral supplementation will be discussed.

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QUANTITIES IN FEEDS

The sharp contrast in variation among TDN, protein, and several elements is pointed out in Table 1. Even with allowances for extreme values due to error, contamination, etc., variability for trace elements within a major category of feed is much greater than that for TDN or protein. Also, the spread between low and high values is greater for trace than major elements, with the exception of calcium and sodium, which were not listed. Certainly a 30 to 50-fold range in trace element content is not unlikely within a given type of forage. Differences may be even greater among different types of forage or feedstuffs. Extremely high values, particularly for iron and aluminum, may reflect soil or other contamination in some cases.

All mineral data, except for sulfur, taken from Penn State summaries have been determined with an emission spectrometer. Essentially the procedures are those reported in (1). This reference lists some of the important precautions to avoid high values from contamination during processing and analysis. Sulfur was determined with a Leco oxidizing unit. A procedure must be modified to include elemental sulfur as well as that in sulfate form.

Another indication of large variability in trace element content of feeds may be found in Table 2. Here the mean coefficients of variation have been listed as taken from a summary of test data. Standard deviations as percents of means are higher for trace than major elements, with the exception of sodium. Also, the coefficient of variation for calcium is relatively high for corn grain. Aluminum has the highest coefficient of variation among the trace elements. Both soil contamination and soil pH greatly affect aluminum values.

Data in Tables 3 and 4 provide expectancies on both trace and major elements for commonly used forages and corn. Most of the samples

TABLE 1. Range in nutritive content of legume-grass forage.[a]

Item	Range	Fold[b] difference
TDN, %	51 – 71	1.4
Crude protein, %	6.6 – 33.2	5.0
Calcium, %	.01 – 2.61	261.0
Phosphorus, %	.07 – .74	10.6
Magnesium, %	.07 – .75	10.7
Sulfur, %	.04 – .38	9.5
Manganese, ppm	6 – 265	44.2
Iron, ppm	10 – 2599	259.9
Copper, ppm	2 – 92	46.0
Zinc, ppm	8 – 300	37.5

[a]Summary of Penn State Forage Testing Service, 1969-73.

[b]Maximum ÷ minimum.

summarized in these tables originated in Pennsylvania and New York. The data should be reasonably indicative of feeds produced in this region or under similar soil and other conditions. Sulfur data are available on a much smaller proportion of the samples and are summarized in Table 5.

Somewhat similar data for grains and by-product ingredients have been published by the National Research Council (9, 10). The data in Tables 6 and 7 for commonly used concentrates have been adapted from these sources. These data were obtained prior to 1958. Also, few samples are represented in some mean values. This is true of those for trace elements, especially zinc and iodine. Insufficient observations exist for some important ingredients such as cottonseed and soybean oil meals.

Many factors may influence the mineral content of forages and other feeds. Underwood (14) has suggested that the most important factors are (a) genus, species, or strain of plant, (b) type of soil, (c) climatic or seasonal conditions during growth, and (d) stage of maturity of the plant. Data on these and other factors have been published more recently (13). The influence of location and soil via pH, parent material, and fertilization has been established in some cases (2, 3, 4, 5, 7, 12, 13, 14). These are landmark publications dealing with applied mineral nutrition.

The effect of geographical origin on the molybdenum and selenium content of feeds is well known. However, less dramatic but impor-

TABLE 2. Mean coefficient of variation for elemental content.[a]

Element	Forages	Corn grain	Combined
		(%)	
Phosphorus	25	22	25
Potassium	32	33	32
Calcium	28	196	73
Magnesium	33	17	30
Sulfur	29	24	28
Sodium	128	318	170
Manganese	75	116	84
Iron	68	83	71
Boron	42	58	46
Copper	57	62	58
Zinc	63	39	57
Aluminum	100	172	116

[a]Summary of Penn State Forage Testing Service, 1969-73.

TABLE 3. Trace element content of various feeds, ppm in dry matter.[a]

Item	Manganese	Iron	Boron	Copper	Zinc	Aluminum
Legume forage (992)[b]						
Mean	44.1	221.7	25.9	13.1	28.1	143.1
SD	49.2	124.9	7.9	8.2	18.8	123.3
Low	8.0	41.0	2.0	2.0	11.0	4.0
High	1080.0	800.0	65.0	214.0	260.0	1000.0
Mixed mainly legume (4014)						
Mean	48.1	222.0	20.2	13.1	27.2	128.8
SD	21.3	142.7	7.2	5.7	12.7	127.7
Low	6.0	10.0	2.0	2.0	8.0	1.0
High	265.0	2599.0	94.0	92.0	300.0	1500.0
Mixed mainly grass (4119)						
Mean	57.3	192.3	11.6	12.0	26.5	105.0
SD	40.0	138.9	5.4	7.0	12.8	113.1
Low	7.0	19.0	1.0	2.0	3.0	2.0
High	1200.0	2463.0	53.0	125.0	255.0	1271.0
Grass forage (352)						
Mean	76.4	184.4	8.3	12.9	27.6	108.0
SD	64.1	141.2	3.8	8.4	10.7	126.0
Low	12.0	32.0	.0	2.0	12.0	7.0
High	689.0	1200.0	26.0	69.0	112.0	1200.0
Corn silage (7179)						
Mean	38.1	200.1	6.5	8.1	30.8	91.8
SD	20.8	131.1	2.6	4.4	21.5	99.0
Low	1.0	5.0	1.0	2.0	3.0	3.0
High	267.0	1800.0	41.0	110.0	416.0	3500.0
Small grain forage (97)						
Mean	62.6	298.8	8.0	11.9	33.2	181.8
SD	41.0	155.9	4.3	7.7	25.5	166.5
Low	9.0	40.0	1.0	2.0	14.0	1.0
High	276.0	900.0	27.0	36.0	212.0	1000.0
Sorghum-sudan forage (91)						
Mean	69.1	320.5	7.7	12.3	41.6	173.6
SD	65.2	278.2	3.2	6.4	38.0	157.8
Low	9.0	67.0	2.0	2.0	15.0	23.0
High	571.0	2000.0	19.0	36.0	315.0	691.0
Ear corn (324)						
Mean	7.3	93.8	3.8	4.7	26.8	21.7
SD	10.9	89.7	2.7	2.7	14.4	43.6
Low	1.0	7.0	.0	1.0	11.0	.0
High	142.0	500.0	36.0	19.0	200.0	500.0
Shelled corn (221)						
Mean	4.8	69.0	3.6	3.7	24.7	10.7
SD	4.0	48.5	1.6	2.5	5.9	15.3
Low	1.0	10.0	1.0	.0	13.0	1.0
High	29.0	464.0	10.0	23.0	58.0	85.0

[a]Summary of Penn State Forage Testing, 1969-73.

[b]Number of samples.

tant differences may exist within a state, county, community, or even on a farm. For example, zinc in Pennsylvania forages may vary appreciably depending upon location, as illustrated in Table 8. Forages grown in Regions 2 and 5 tend to contain more zinc. The reasons are not apparent here, but observation of many tests over years suggests that forages grown

TABLE 4. Major element content of various feeds, percent in dry matter.[a]

Item	Phosphorus	Potassium	Calcium	Magnesium	Sodium
Legume forage (992)[b]					
Mean	.30	2.55	1.18	.24	.024
SD	.05	.61	.27	.07	.017
Low	.14	.21	.03	.10	.001
High	.56	4.93	2.23	.58	.100
Mixed mainly legume (4014)					
Mean	.29	2.26	1.02	.22	.018
SD	.06	.60	.28	.07	.015
Low	.07	.42	.01	.07	.000
High	.74	9.63	2.61	.75	.110
Mixed mainly grass (4119)					
Mean	.23	1.79	.65	.18	.013
SD	.06	.55	.28	.06	.016
Low	.05	.30	.10	.03	.000
High	.81	4.70	2.73	.79	.390
Grass forage (352)					
Mean	.22	1.68	.49	.16	.014
SD	.07	.61	.20	.06	.019
Low	.09	.24	.10	.04	.000
High	.56	4.04	1.58	.42	.110
Corn silage (7179)					
Mean	.23	1.07	.27	.18	.005
SD	.05	.27	.11	.05	.014
Low	.01	.02	.01	.01	.000
High	.93	3.28	1.88	.55	.350
Small grain forage (97)					
Mean	.32	2.29	.44	.16	.030
SD	.09	.81	.20	.05	.031
Low	.14	.49	.06	.07	.001
High	.76	5.30	1.22	.29	.100
Sorghum-sudan forage (91)					
Mean	.24	1.73	.48	.28	.008
SD	.06	.74	.23	.12	.012
Low	.07	.12	.12	.06	.001
High	.44	4.00	1.83	.58	.071
Ear corn (324)					
Mean	.28	.49	.05	.12	.007
SD	.08	.18	.10	.02	.020
Low	.14	.26	.01	.01	.000
High	1.14	2.96	1.15	.25	.100
Shelled corn (221)					
Mean	.31	.42	.03	.12	.003
SD	.05	.13	.06	.02	.010
Low	.19	.24	.01	.06	.000
High	.59	1.41	.72	.20	.100

[a]Summary of Penn State Forage Testing, 1969-73.

[b]Number of samples.

closer to industrial centers may be higher in some trace elements. Perhaps some of this may be due to air pollution, use of industrial by-products on soils, and run-off from disposal sites for industrial wastes. Forages grown in an area with slate mines may sometimes contain 80 to 220 ppm zinc. This is 3 to 7 times higher than expected zinc. Molybdenum toxicity has

TABLE 5. Sulfur content of various feeds, dry matter basis.[a]

Item	No. samples	Mean	Low	High	Standard deviation
		%	%	%	± %
Legume forage	39	.26	.14	.43	.07
Mixed mainly legume	121	.23	.04	.38	.06
Mixed mainly grass	71	.20	.12	.35	.06
Grass forage	4	.20	.14	.29	.07
Corn silage	249	.14	.04	.22	.04
Small grain forage	1	.21	...	...	...
Sorghum-sudan	3	.10	.08	.14	.03
Ear corn	18	.13	.08	.22	.04
Shelled corn	8	.14	.10	.19	.03

[a]Summary of Penn State Forage Testing, 1969-73.

TABLE 6. Zinc ppm in forages by major land resource areas in Pennsylvania.[a]

Region[b]	Corn silage		Legume-Grass hay		Grass-Legume hay	
	No. samples	ppm	No. samples	ppm	No. samples	ppm
1	879	31	328	27	679	24
2	278	37	189	32	115	30
3	295	30	123	25	158	25
4	1478	29	874	26	351	27
5	974	30	355	31	214	31

[a]Content on a dry matter basis for samples tested from 1969 to 1973.

[b]Regions are described as follows: (1) Glaciated Allegheny Plateau and Catskill Mountains (Northwest and Northeast), (2) Central Allegheny Plateau, (3) Eastern Allegheny Plateau and Mountains, (4) Northern Appalachian Ridge and Valleys (South Central), and (5) Northern Piedmont (Southeast).

TABLE 7. Trace mineral content of various concentrates, dry matter basis.[a]

Item	Manganese	Iron	Copper	Zinc	Cobalt	Iodine
	(ppm)					
Barley						
No. samples	(73)	(41)	(33)	(3)	(27)	...
Mean	18.2	60.0	8.6	17.1	.117	...
Low	2.4	40.0	1.3	11.9	.000	...
High	29.9	100.0	20.0	20.9	.321	....
Beet pulp, dried						
No. samples	(39)	(27)	(31)	(1)	(26)	...
Mean	38.5	331.0	13.9	7.0	.112	...
Low	12.1	85.0	8.4	...	.023	...
High	77.9	600.0	22.7	...	.116	...
Brewers' grains, dried						
No. samples	(29)	(22)	(16)	...	(15)	...
Mean	40.7	271.6	23.1	...	.067	...
Low	21.1	100.0	5.5	...	.044	...
High	56.1	410.0	45.3	...	.110	...
Citrus pulp, dried						
No. samples	(16)	(14)	(8)	(1)	(4)	...
Mean	7.5	183.1	6.3	16.0	.236	...
Low	1.1	94.0	2.0	...	.066	...
High	19.4	303.0	14.5	...	.704	...

TABLE 7. (Continued) Trace mineral content of various concentrates, dry matter basis.[a]

Item	Manganese	Iron	Copper	Zinc	Cobalt	Iodine
	(ppm)					
Corn, dent						
No. samples	(568)	(518)	(463)	(2)	(460)	(16)
Mean	5.7	20.0	2.4	19.6	.022	.344
Low	.7	10.0	.9	12.1	.002	.064
High	53.9	100.0	9.0	26.8	.299	.704
Corn distillers w sol.						
No. samples	(10)	(8)	(2)	...	(2)	...
Mean	30.9	334.1	67.1	...	.120	...
Low	15.6	200.0	56.1	...	...	...
High	67.3	600.0	78.5	...	...	...
Corn gluten feed						
No. samples	(45)	(32)	(33)	...	(26)	...
Mean	26.3	514.0	52.7	...	.097	...
Low	8.8	260.0	13.0	...	.022	...
High	42.2	955.0	89.3	...	.286	...
Cottonseed meal, solv.						
No. samples	(5)	(3)	(3)	...	(3)	...
Mean	21.8	167.0	23.3	...	.086	...
Low	16.2	110.0	16.3	...	.033	...
High	30.1	246.0	32.6	...	.176	...
Hominy feed, yel.						
No. samples	(17)	(12)	(5)	...	(3)	...
Mean	17.8	109.0	10.7	...	.061	...
Low	11.4	10.0	7.9	...	.048	...
High	30.6	260.0	13.9	...	.066	...
Oats						
No. samples	(199)	(88)	(73)	...	(19)	...
Mean	42.9	80.0	6.6	...	.064	...
Low	20.0	20.0	2.4	...	.000	...
High	203.5	300.0	25.7	...	.321	...
Molasses, cane						
No. samples	(9)	(9)	(8)	...	(4)	...
Mean	56.6	251.0	80.0	...	1.213	...
Low	12.8	130.0	33.4	...	.224	...
High	83.8	429.0	137.1	...	3.485	...
Sorghum						
No. samples	(42)	(44)	(38)	(2)	(22)	...
Mean	16.2	50.0	10.8	15.4	.304	...
Low	.0	.0	2.0	11.8	.040	...
High	27.3	180.0	19.1	18.9	.737	...
Soybean meal, solv.						
No. samples	(7)	(9)	(8)	...	(6)	...
Mean	30.8	147.0	16.0	...	.103	...
Low	24.9	110.0	13.6	...	.031	...
High	33.9	240.0	18.3	...	.176	...
Steamed bone meal						
No. samples	(57)	(63)	(56)	(36)	(17)	...
Mean	31.9	882.4	17.1	446.0	.065	...
Low	2.0	159.0	.9	51.3	.044	...
High	92.4	2829.0	33.4	1835.9	.110	...
Wheat bran						
No. samples	(44)	(29)	(30)	...	(24)	...
Mean	129.9	193.0	13.8	...	.108	...
Low	90.0	88.0	4.4	...	.031	...
High	164.3	270.0	29.9	...	.178	...
Wheat std. mids						
No. samples	(20)	(13)	(10)	...	(10)	...
Mean	132.0	115.9	11.1	...	.094	...
Low	103.4	83.0	22.2	...	.079	...
High	157.7	192.0	28.2	...	.130	...

[a]Adapted from National Academy of Science, National Research Council Publications No. 449 and 585.

TABLE 8. Major mineral content of various concentrates, dry matter basis.[a]

Item	Phosphorus	Potassium	Calcium	Magnesium	Sulfur	Sodium	Chlorine
				(%)			
Barley							
No. samples	(331)	(233)	(325)	(234)	(213)	(10)	(14)
Mean	.47	.63	.09	.14	.19	.02	.13
Low	.28	.33	.03	.01	.10	.01	.09
High	.92	.99	.41	.23	.35	.06	.17
Beet pulp, dried							
No. samples	(57)	(8)	(56)	(14)	(4)	(6)	(1)
Mean	.11	.23	.75	.30	.22	.19	.04
Low	.05	.15	.36	.06	.13	.11	...
High	.17	.39	1.03	.43	.31	.23	...
Brewers' grains, dried							
No. samples	(37)	(5)	(37)	(7)	(4)	(1)	(4)
Mean	.54	.09	.29	.15	.34	.28	.20
Low	.36	.04	.14	.03	.05	...	.06
High	.68	.18	.65	.31	.51	...	.26
Citrus pulp, dried							
No. samples	(38)	(4)	(38)	(20)	...	...	...
Mean	.13	.69	2.18	.18	...	...	...
Low	.09	.10	1.24	.02	...	...	...
High	.24	1.41	3.55	.50	...	...	...
Corn, dent							
No. samples	(586)	(88)	(571)	(88)	(38)	(53)	(72)
Mean	.31	.33	.03	.14	.14	.01	.06
Low	.09	.20	.00	.08	.10	.00	.02
High	.24	.73	.35	.90	.19	.06	.09
Corn distillers w sol.							
No. samples	(22)	(8)	(22)	(13)	(5)	(3)	(3)
Mean	.74	.71	.19	.27	.33	.39	.19
Low	.43	.22	.11	.09	.24	.18	.17
High	1.02	1.13	.28	.38	.40	.79	.19
Corn gluten feed							
No. samples	(82)	(29)	(59)	(31)	(26)	(3)	(7)
Mean	.85	.66	.51	.32	.24	1.05	1.24
Low	.38	.62	.03	.29	.06	1.03	.06
High	1.20	1.33	1.08	.87	1.40	1.10	1.04
Cottonseed meal, solv.							
No. samples	(16)	(3)	(14)	(4)	(1)	(3)	(2)
Mean	1.20	1.61	.16	.64	.23	.06	.04
Low	.65	1.03	.07	.37	...	.01	.04
High	1.70	2.20	.26	.82	...	.11	.05

been found in plants and animals located in the vicinity of zinc and molybdenum smelters. Some of the extremely high trace elements in Table 3 were obtained in forages from farms with animal health problems which apparently resulted from intake of industrially contaminated forages.

SUPPLEMENTATION PROBLEMS

Neither universal products nor general recommendations can insure that all cows on all farms will receive proper amounts of mineral elements at all times. Yet, this is what some dairymen are led to believe for various reasons. Further, some farmers believe that home-produced feeds will contain adequate amounts of most elements, if they fertilize according to soil tests or get good yields. Unfortunately, some mineral nutrition problems result from a differential requirement of the animal over that of plants or from low availability of an element to the animal (7).

Proper use of forage and feed testing with mineral analyses combined with custom feed programming offers the best approach to reasonably good mineral nutrition. The use of

TABLE 8. (Continued) Major mineral content of various concentrates, dry matter basis.[a]

Item	Phosphorus	Potassium	Calcium	Magnesium	Sulfur	Sodium	Chlorine
	(%)						
Hominy feed, yel.							
No. samples	(22)	(1)	(22)	(2)	...	(1)	...
Mean	.57	.57	.06	.04	...	.14	...
Low	.30	...	.02	.02	...	...	...
High	.87	...	.12	.06	...	...	...
Oats							
No. samples	(273)	(83)	(227)	(77)	(15)	(18)	(19)
Mean	.39	.42	.11	.19	.23	.07	.11
Low	.05	.22	.04	.03	.15	.01	.05
High	1.02	.89	.48	.29	.31	.16	.19
Molasses, cane							
No. samples	(32)	(9)	(35)	(19)	(15)	(5)	(4)
Mean	.11	3.20	1.20	.47	.46	.23	3.69
Low	.01	2.16	.32	.16	.10	.10	2.60
High	.25	3.64	2.20	.87	.97	.53	4.35
Sorghum							
No. samples	(235)	(16)	(227)	(23)	(6)	(9)	(7)
Mean	.35	.38	.05	.19	.18	.05	.10
Low	.10	.28	.01	.02	.15	.01	.07
High	.52	.50	.53	.25	.21	.09	.14
Soybean meal, solv.							
No. samples	(34)	(6)	(35)	(8)	(1)	(6)	(1)
Mean	.75	2.20	.36	.30	.48	.38	.00
Low	.50	2.00	.23	.00	...	.04	...
High	1.09	2.30	.96	.45	...	.62	...
Steamed bone meal							
No. samples	(109)	...	(109)	(45)	(40)	(18)	...
Mean	14.28	.18	30.44	.64	.23	.48	...
Low	8.34	...	22.75	.11	.07	.40	...
High	18.35	...	36.65	1.19	.91	.55	...
Wheat bran							
No. samples	(86)	(11)	(84)	(10)	(9)	(9)	(7)
Mean	1.31	1.39	.16	.62	.25	.07	.05
Low	.10	.93	.07	.50	.19	.01	.02
High	1.91	1.77	.56	.80	.36	.11	.10
Wheat std. mids							
No. samples	(53)	(33)	(30)	(34)	(32)	(1)	(3)
Mean	1.01	1.09	.17	.41	.06	.25	.03
Low	.73	1.06	.07	.40	...	...	.03
High	1.35	1.37	.50	.56	...	...	.04

[a]Adapted from National Academy of Science, National Research Council Publications No. 449 and 585.

multiple product lines designed to provide flexibility in mineral content of finished feeds affords a satisfactory means of improving mineral nutrition. The use of manufactured protein concentrates without added minerals, at least the major ones, provides still another alternative.

Trace mineral tests must be used with caution in feed programming. Extreme values may occur due to contamination before or after sampling, faulty procedures, and improperly operated or malfunctioning equipment. Thus, it is best to use values that are consistent with past test reports from a farm when unreasonable values are encountered.

It is extremely important to use sound assumptions, good expectancy data, and reasonable allowances for developing either general recommendations or universal formulas for supplements. Should one base supplementation on average values for forage and concentrates? Or should values be used that range from one-half to more than one standard deviation below average? In regard to trace elements, it appears best to use a value that at least approaches one standard deviation below mean values. This theoretically would make the recommendations adequate about 84% of the time. As illustrated in Table 9, values for a given element may not fit a normal distribution curve. They may be skewed with relatively few samples close to the mean and considerably more values falling below the mean than above it.

The minimum allowances which we prefer to use in general feed programming are in Table 10. Phosphorus allowances approximate those of the 1971 NRC publication (11). Most trace mineral allowances agree with those of Jacobson et al. (8).

Quantities of trace minerals needed in the grain mixture to balance a commonly used ration are in Table 11. Likewise, amounts of minor elements needed in a trace mineral salt to be used in supplementing a corn and soybean oil meal mixture are given. Assumptions include feeding a cow weighing 545.5 kg and producing 22.7 kg of milk testing 4% fat. In addition, 65% of the total dry matter was furnished by a forage ration consisting of 50% corn silage and 50% mixed mainly legume forage on a dry matter basis. If mean expectancies are used, one could feed reasonably certain that needs were being met only 50% of the time or less. When an expectancy of one standard deviation below mean is used, one may be meeting needs about 84% of the time.

TABLE 9. Distribution of iron in mixed mainly legume forages.[a]

ppm	Percent of samples
30 – 60	1.5
60 – 90	5.9
90 – 120	5.2
120 – 150	19.3
150 – 180	14.8
180 – 210	11.1
210 – 240	2.2
240 – 270	3.0
270 – 300	1.5
300 – 330	5.9
330 – 360	.7
360 – 390	2.2
390 – 420	4.4
420 – 450	1.5
450 – 480	1.5
480 – 510	19.3

[a]135 samples randomly selected from 1973-74 testing year at Penn State. Mean 255.9 + 150.1 ppm; range 38 to 500 ppm. Skewed positively with 61.5% of the samples below the mean and 38.5% above the mean.

TABLE 10. Mineral allowances for dairy cows.[a]

Element	Amount
Calcium, %	.68 – .76
Phosphorus, %	.38
Potassium, %	.70
Magnesium, %	.22
Sulfur, %	.20
Manganese, ppm	44
Iron, ppm	150
Copper, ppm	11
Zinc, ppm	70
Cobalt, ppm	1
Iodine, ppm	2

[a]Levels expressed on a dry matter basis.

For comparison, trace minerals in a popular manufactured dairy feed and a widely used trace mineral salt are shown in parentheses. Manganese usually approaches or exceeds needs in products used for supplementation. This probably is a carry-over from poultry nutrition, rather than the result of good formulation for dairy purposes. Zinc supplementation is most likely inadequate. Iron may be lacking in some fortifications. Copper, cobalt, and iodine may be insufficient in some cases. Classical cobalt, copper, and, to a lesser extent, iodine deficiencies have been found in Pennsylvania despite usual supplementation with these elements. This is not surprising in view of the information in Table 11 and elsewhere in this paper. Supplementation may be inadequate to meet minimum needs. Also, various factors or imbalances may increase requirements for certain elements. For example, goitrogens may increase iodine requirement. Availability of minerals in forages may also vary from time to time, as in the case of magnesium.

While some dairy herds may suffer from a lack of minerals, others may be over-supplemented with major and trace elements to the point of decreased profits and reduced performance. It is not uncommon to find dairymen who provide trace mineral supplementation via

TABLE 11. Possible elemental quantities for supplementary feeding.

Basis:	Mean		One standard deviation below mean	
Element	Concentrate mix[a]	Trace mineral salt[b]	Concentrate mix[a]	Trace mineral salt[b]
	(ppm)	(%)	(ppm)	(%)
Manganese	39	.310	78 (76)[c]	.690 (.600)[d]
Iron	31	.000	245 (363)	1.800 (.200)
Copper	10	.044	19 (10)	.130 (.060)
Zinc	123	.934	143 (105)	1.112 (.010)
Cobalt	2.3	.023	2.3 (. . .)	.023 (.015)
Iodine	3.1	.028	4.0 (. . .)	.037 (.016)

[a]Total of the element (natural + supplemental) necessary to balance the forage ration using the grain mixture or complete dairy feed as the vehicle.

[b]Element necessary in a trace mineral salt to provide needed supplementation when used at 1% in a corn-soybean oil meal mixture.

[c]In a popular manufactured dairy feed.

[d]In a popular trace mineral salt.

as many as 6 to 8 sources. To illustrate, some dairymen using a grains plus supplement mixture may furnish supplementary trace minerals via each of the following means: (a) manufactured dairy concentrate, (b) trace mineral salt in mix, (c) trace mineralized phosphorus supplement in mix, (d) liquid protein supplement free-choice, (e) trace mineral salt free-choice, (f) commercial mineral supplement free-choice, and (g) nonprotein nitrogen (NPN) corn silage made with a commercial additive.

This kind of supplementation should be discouraged for numerous reasons. Trace mineral supplementation via one or two sources in forced feeding and one in free-choice feeding should be adequate in most cases, if well-formulated products are used. We have encountered herds with appetite and other problems where 5 to 7% of the grain mixture consisted of supplementary mineral compounds and premixes, as recommended by some computer programs.

NEEDS

Additional information is necessary in several areas, as follows:

(a) More research is needed to develop improved allowances for use in feed programming and formulation of commercial products.

(b) Further studies are necessary on the use of chelated minerals from both the basic and applied standpoints.

(c) Guarantees or specification sheets for manufactured feeds and concentrates should be expanded to include mineral content in all cases, not just for pre-mixes, super-concentrates, or feeds tagged under the feed control laws of certain states.

(d) Improved compilations of the content of mineral and other nutrients in feeds are vital to aid in improving the nutrition of farm animals.

Further elaboration on the fourth point is justified. Compilations which provide as full information as possible on well-described feeds should be published on a more regular basis. The format preferably should include standard deviations and coefficients of variation. The efforts of the National Research Council in the past (9, 10) are to be commended. The current effort being made by the International Feedstuffs Institute at Utah State University (6) also is commendable. It provides the basis upon which a more satisfactory job of compilation and publication could be accomplished. To date, however, funding and voluntary efforts appear inadequate to serve the needs of the animal industry in today's world.

A more deliberate effort may be needed to make certain that the number of samples included in a meaningful compilation approach a minimum of 100 to 150 for any particular analysis of an important feed. Further compilations probably should be published at least every 5 yr to keep values abreast of changing technology in production and processing. Preferably, only data within such a limited period should be included. Additional regionalization of data based on known differences in mineral content of feeds or special environmental conditions is necessary. While a large, highly specific as well as detailed compilation is necessary for certain situations, the greater need is for one that covers in detail only the important forages and concentrates in somewhat broader categories. Such a version is badly needed by applied nutritionists and essential to improvements in feeding.

More attention must be paid to mineral nutrition, especially trace elements, in feeding dairy cattle. Too many people in feed trade and educational circles have not put sufficient emphasis on mineral nutrition. This has encouraged many entrepreneurs, well meaning and otherwise, to market minerals directly to dairymen and livestock farmers. Because of the inherent inefficiencies of this approach, the costs of these minerals to farmers has been considerably higher than necessary. Nevertheless, some good has been done in more closely meeting nutritional needs and in encouraging greater efforts on the part of researchers and the feed trade.

There is no substitute for a ration that is well balanced from the chemical and physical standpoints. A balanced ration is essential to good performance under both farm and research conditions. Whenever possible, experimental rations should be isomineralized as well as isocaloric, isonitrogenous, and otherwise nutritionally adequate. Poorly formulated rations can result in faulty conclusions or severely limit the usefulness of the research in practical feeding.

SUMMARY

The trace element content of feeds is extremely variable. Differences between high and low values for a given type of feed are wide for many elements. There is a lack of data for certain elements in some widely used feeds. Zinc is the element most likely to be inadequate under current supplementation practices. Manganese is the least likely to be limiting. Cobalt, copper, iodine, and iron are apt to be provided in insufficient amounts with current practices.

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