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Nutritional Requirements of Beef Cattle - Management and Nutrition - Merck Veterinary Manual

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Beef cattle production, whether on range, improved pasture, or in the feedlot, is most economic when feedstuffs are used effectively. Young growing grass or other high-quality pasture crops usually supply ample nutrients, such that mature and young growing cattle can consume sufficient good-quality mixed pasture (grasses and legumes) for normal growth and maintenance. However, mature pasture, crop residues, or forage crops harvested in a manner that results in shattering, leaching, or spoilage may be so reduced in nutritive value (particularly energy, protein, phosphorus, and provitamin A or β-carotene) that they are suitable only in a maintenance ration for adult cattle. Such feedstuffs should be supplemented if used for any other purposes.

The mineral content of forages is influenced by the corresponding mineral levels in the soil and by excess levels of some minerals that reduce the availability of others. Mature forages also may be lower in mineral content, especially phosphorus. Normally, supplemental minerals are supplied in a free-choice mineral mix or force-fed in the total mixed ration.

Certain nutrients are required by beef cattle in the daily ration, whereas others can be stored in the body. When body stores of a nutrient are high, eg, vitamin A, dietary supplementation is unnecessary until such stores are depleted. However, it may be difficult to determine when body stores have been depleted until advanced signs of deficiency start to appear.

The following are dietary requirements for maintenance, growth, finishing, reproduction, and lactation in beef cattle.

Water, although not considered a nutrient per se, is required for regulation of body temperature, as well as for growth, reproduction, lactation, digestion, metabolism, excretion, hydrolysis of nutrients, transportation of nutrients and waste in the body, joint lubrication, plus many more functions. Restricting water intake results in impaired performance. An animal will expire more quickly from a water deficiency than from a deficiency of any nutrient.

Because feeds themselves contain water, and the metabolism of

ingested feeds releases water (called metabolic water), not all of the animal's water needs have to be met by drinking water. Thirst is the result of need, and animals drink to meet this need. The need for water results from an increase in the electrolyte concentration in the body fluids, which activates the thirst mechanism.

Many factors, including temperature and body weight, affect water consumption in cattle. An 800-lb (364-kg) heifer at an environmental temperature of 4.4°C (40°F) can be expected to consume 6.3 gal. (23 L) per day; at 21°C (70°F), this will increase to 9.2 gal. (34.8 L). At the same 4.4°C temperature, a 400-lb (182-kg) heifer will consume ~4 gal. (15.1 L). Note that water consumption and body weight are not correlated by a straight-line relationship. A 900-lb (409-kg) lactating cow at the 4.4°C temperature will consume 11.4 gal. (43.1 L) per day.

Productive animals need essentially two types of energy. Energy of maintenance is that needed to maintain respiration, circulation, digestion, etc. Therefore, in calculating total energy needs, the net energy for maintenance, or NE_m, must be considered. The energy required for growth and reproduction is called the net energy for production, or NE_g. It is the amount of energy intake deposited as muscle and/or fat in animals gaining weight. (See table: Mean Nutrient Content of Feeds Commonly Used in Beef Cattle Diets [a] through Nutrient Requirements of Growing Beef Bulls [a].)

Except for preruminant calves, beef cattle can meet their maintenance energy requirements from roughages of reasonably good quality (green, leafy, fine-stemmed, free of mold and weeds). A shortage of energy may exist on overstocked pastures, with inadequate feed allowance or poor-quality forages, or during a drought. For production, additional energy from concentrates or co-product feeds may be necessary, especially when forages of fair to poor quality are consumed.

Especially in cold weather, roughages of varying quality may have similar maintenance energy values. Heat released during digestion and assimilation—called "heat increment"—contributes to the maintenance of body temperature for wintering stock.

Mean Nutrient Content of Feeds Commonly Used in Beef Cattle Diets [a]

Feedstuff	DE (Mcal/kg)	ME (Mcal/kg)	NE_m (Mcal/kg)	NE_g (Mcal/kg)	TDNs (%)	Crude Protein (%)	Crude Fiber (%)	Ash (%)	NDF (%)	ADF (%)

Feedstuff	DE (Mcal/kg)	ME (Mcal/kg)	NE_m (Mcal/kg)	NE_g (Mcal/kg)	TDNs (%)	Crude Protein (%)	Crude Fiber (%)	Ash (%)	NDF (%)	ADF (%)
Alfalfa (*Medicago sativa*)										
Fresh	2.73	2.24	1.38	0.80	62	18.9	26.5	10.5	47.1	36.8
Fresh, late vegetative	2.91	2.39	1.51	0.92	66	22.2	24.2	10.2	30.9	24.0
Fresh, full bloom	2.22	1.81	0.97	0.42	50	19.3	30.4	10.9	4.79	3.7
Hay	2.65	2.17	1.31	0.74	60	18.6	26.1	8.6	43.9	33.8
Hay, sun-cured, early bloom	2.65	2.17	1.31	0.74	60	19.9	28.5	9.2	39.3	31.9
Hay, sun-cured, mid bloom	2.56	2.10	1.24	0.68	58	18.7	28.0	8.5	47.1	36.7
Hay, sun-cured, full bloom	2.43	1.99	1.14	0.58	55	17.0	30.1	7.8	48.8	38.7
Silage	2.78	2.28	1.41	0.83	63	19.5	25.4	9.5	47.5	37.5
Barley (*Hordeum vulgare*)										
Grain	3.84	3.03	2.06	1.40	88	13.2	3.37	2.4	18.1	5.8
Silage	2.65	2.17	1.31	0.74	60	11.9	2.92	8.3	56.8	33.9
Beet pulp, dried	3.26	2.68	1.76	1.14	74	9.8	20.0	5.3	44.6	27.5
Bermuda grass (*Cynodon dactylon*)										

[a] Dry-matter basis; DE, digestible energy; ME, metabolizable energy; NE_m, net energy for mai
energy for gain; TDNs, total digestible nutrients; NDF, neutral detergent fiber; ADF, acid deterg

Adapted, with permission, from *Nutrient Requirements of Beef Cattle*, 2000, National Academy
National Academy Press, Washington, DC.

Feedstuff	DE (Mcal/kg)	ME (Mcal/kg)	NE_m (Mcal/kg)	NE_g (Mcal/kg)	TDNs (%)	Crude Protein (%)	Crude Fiber (%)	Ash (%)	NDF (%)	ADF (%)
Fresh	2.82	2.31	1.44	0.86	64	12.6	28.4	8.1	73.3	36.8
Hay, sun-cured	2.16	1.77	0.93	0.39	49	7.8	2.7	76.6	—	—
Brewer's grains, dried	2.39	2.39	1.51	0.91	66	29.2	7.8	4.18	48.7	31.2
Citrus pulp, dried	3.62	2.96	2.00	1.35	82	6.7	12.8	6.6	23.0	23.0
Corn (*Zea mays indentata*)										
Distiller's grains, dried	3.88	3.18	2.18	1.50	90	30.4	6.9	4.6	46.0	21.3
Gluten feed	3.53	2.89	1.94	1.30	80	23.8	7.5	6.9	36.2	12.7
Grain, cracked	3.92	3.25	2.24	1.55	90	9.8	2.3	1.5	10.8	3.3
Silage, well-eared	3.17	2.60	1.69	1.08	72	8.7	19.5	3.6	46.0	26.6
Cotton (*Gossypium* spp)										
Seed	3.97	3.25	2.24	1.55	90	24.4	25.6	4.2	51.6	41.8
Meal	3.31	2.71	1.79	1.16	75	46.1	13.2	7.0	28.9	17.9
Molasses, cane	3.17	2.60	1.70	1.08	72	5.8	0.5	13.3	—	0.4
Oats	3.40	2.78	1.85	1.22	77	13.6	12.0	3.3	29.3	14.0

[a] Dry-matter basis; DE, digestible energy; ME, metabolizable energy; NE_m, net energy for mai
energy for gain; TDNs, total digestible nutrients; NDF, neutral detergent fiber; ADF, acid deterg

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Feedstuff	DE (Mcal/kg)	ME (Mcal/kg)	NE_m (Mcal/kg)	NE_g (Mcal/kg)	TDNs (%)	Crude Protein (%)	Crude Fiber (%)	Ash (%)	NDF (%)	ADF (%)
Sorghum (*Sorghum bicolor*), grain	3.62	2.96	2.00	1.35	82	12.6	2.76	1.9	16.1	6.4
Soybeans (*Glycine max*), meal	3.70	3.04	2.06	1.40	84	51.8	5.4	6.9	10.3	7.0
Wheat (*Triticum aestivum*)										
Wheat bran	3.09	2.53	1.63	1.03	70	17.4	11.3	6.6	42.8	14.0
Fresh, early vegetative	3.22	2.64	1.73	1.11	73	27.4	17.4	13.3	46.2	28.4

[a] Dry-matter basis; DE, digestible energy; ME, metabolizable energy; NE_m, net energy for mai
energy for gain; TDNs, total digestible nutrients; NDF, neutral detergent fiber; ADF, acid deterg

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Nutrient Requirements of Pregnant Replacement Beef Cows [a]

Months Since Conception:	1	2	3	4	5	6	7	8	9
NE_m required (Mcal/day)									
Maintenance	5.98	6.14	6.30	6.46	6.61	6.77	6.92	7.07	7.23
Growth	2.29	2.36	2.42	2.48	2.54	2.59	2.65	2.71	2.77
Pregnancy	0.03	0.07	0.16	0.32	0.64	1.18	2.08	3.44	5.37
Total	8.31	8.57	8.87	9.26	9.79	10.55	11.65	13.23	15.37
MP required (g/day)									

Months Since Conception:	1	2	3	4	5	6	7	8	9
Maintenance	295	303	311	319	326	334	342	349	357
Growth	118	119	119	119	119	117	115	113	110
Pregnancy	2	4	7	18	27	50	88	151	251
Total	415	425	437	457	472	501	545	613	718
Calcium required (g/day)									
Maintenance	10	11	11	11	12	12	12	13	13
Growth	9	9	9	8	8	8	8	8	8
Pregnancy	0	0	0	0	0	0	12	12	12
Total	19	19	20	20	20	20	33	33	33
Phosphorus required (g/day)									
Maintenance	8	8	8	9	9	9	10	10	10
Growth	4	4	3	3	3	3	3	3	3
Pregnancy	0	0	0	0	0	0	7	7	7
Total	12	12	12	12	12	13	20	20	20
Average daily gain (kg/day)									
Growth	0.39	0.39	0.39	0.39	0.39	0.39	0.39	0.39	0.39
Pregnancy	0.03	0.05	0.08	0.12	0.19	0.28	0.40	0.57	0.77
Total	0.42	0.44	0.47	0.51	0.58	0.67	0.79	0.96	1.16
Body wt (kg)									
Shrunk body	332	343	355	367	379	391	403	415	426
Gravid uterus mass	1	3	4	7	12	19	29	44	64
Total (kg)	333	346	359	374	391	410	432	459	490
Total (lb)	733	761	790	823	860	902	950	1,010	1,078
[a] Mature weight, 533 kg (1,173 lb); calf birth weight, 40 kg (88 lb); age at breeding, 15 mo; breed code Angus; see Table: Mean Nutrient									

Months Since Conception:	1	2	3	4	5	6	7	8	9
Content of Feeds Commonly Used in Beef Cattle Diets [a] for abbreviations. The concentration of vitamin A in all diets should be 2,200 IU/kg (1,000 IU/lb) of dry matter. Adapted, with permission, from *Nutrient Requirements of Beef Cattle*, 2000, National Academy of Sciences, National Academy Press, Washington, DC.									

Nutrient Requirements of Beef Cows [a]

Months Since Calving:	1	2	3	4	5	6	7	8	9	10	11	12
NE_m required (Mcal/day)												
Maintenance	10.25	10.25	10.25	10.25	10.25	10.25	8.54	8.54	8.54	8.54	8.54	8.54
Lactation	4.78	5.74	5.17	4.13	3.10	2.23	0	0	0	0	0	0
Pregnancy	0	0	0.01	0.03	0.07	0.16	0.32	0.64	1.18	2.08	3.44	5.37
Total	15.03	15.99	15.43	14.41	13.42	12.64	8.87	9.18	9.72	10.62	11.98	13.91
MP required (g/day) [b]												
Maintenance	422	422	422	422	422	422	422	422	422	422	422	422
Lactation	349	418	376	301	226	163	0	0	0	0	0	0
Pregnancy	0	0	1	2	4	7	14	27	50	88	151	251
Total (g)	771	840	799	725	652	592	436	449	472	510	573	673
Total (lb)	1.7	1.9	1.8	1.6	1.4	1.3	1.0	1.0	1.0	1.1	1.3	1.5
Calcium required (g/day) [b]												
Maintenance	16	16	16	16	16	16	16	16	16	16	16	16
Lactation	16	20	18	14	11	8	0	0	0	0	0	0
Pregnancy	0	0	0	0	0	0	0	0	0	12	12	12
Total	32	36	34	30	27	24	16	16	16	28	28	28

Months Since Calving:	1	2	3	4	5	6	7	8	9	10	11	12
Phosphorus required (g/day)[b]												
Maintenance	13	13	13	13	13	13	13	13	13	13	13	13
Lactation	9	11	10	8	6	4	0	0	0	0	0	0
Pregnancy	0	0	0	0	0	0	0	0	0	5	5	5
Total	22	24	23	21	19	17	13	13	13	18	18	18
Gain in weight from pregnancy/day[b]												
Grams	0	0	20	30	50	80	120	190	280	400	570	770
Pounds	0	0	0.04	0.07	0.11	0.18	0.26	0.42	0.62	0.88	1.25	1.70
Milk production/day												
Kilograms	6.7	8.0	7.2	5.8	4.3	3.1	0	0	0	0	0	0
Pounds	14.7	17.6	15.8	12.8	9.5	6.8	0	0	0	0	0	0
Weight of conceptus												
Kilograms	0	0	1	1	3	4	7	12	19	29	44	64
Pounds	0	0	2	2	7	9	15	26	42	64	97	141

[a] Mature weight, 533 kg (1,172 lb); calf birth weight, 40 kg (88 lb); age at calving, 60 mo; peak milk, 8 kg (17.6 lb); age of calf at weaning, 30 wk; breed code Angus; milk protein, 3.4%; calving interval, 12 mo; see Table: Mean Nutrient Content of Feeds Commonly Used in Beef Cattle Diets [a] for abbreviations. Crystalline vitamin A should be added at a level of 2,200 IU/kg (1,000 IU/lb) dry matter feed.

[b] No allowance made for gain because these are mature cows.

Adapted, with permission, from *Nutrient Requirements of Beef Cattle*, 2000, National Academy of Sciences, National Academy Press, Washington, DC.

Nutrient Requirements of Growing and Finishing Beef Cattle [a]

Body Weight in kg (lb)	200 (440)	250 (550)	300 (660)	350 (770)	400 (880)	450 (990)

Body Weight in kg (lb)	200 (440)	250 (550)	300 (660)	350 (770)	400 (880)	450 (990)
Maintenance requirement						
NE_m (Mcal/day)	4.1	4.84	5.55	6.23	6.89	7.52
MP (g/day)	202	239	274	307	340	371
Calcium (g/day)	6	8	9	11	12	14
Phosphorus (g/day)	5	6	7	8	10	11
Growth requirement (Average daily gain in kg [lb])						
NE_g required for gain (Mcal/day)						
0.5 (1.1)	1.27	1.50	1.72	1.93	2.14	2.33
1.0 (2.2)	2.72	3.21	3.68	4.13	4.57	4.99
1.5 (3.3)	4.24	5.01	5.74	6.45	7.13	7.79
2.0 (4.4)	5.81	6.87	7.88	8.84	9.77	10.68
2.5 (5.5)	7.42	8.78	10.06	11.29	12.48	13.64
MP required for gain (g/day)						
0.5 (1.1)	154	155	158	157	145	133
1.0 (2.2)	299	300	303	298	272	246
1.5 (3.3)	441	440	442	432	391	352
2.0 (4.4)	580	577	577	561	505	451
2.5 (5.5)	718	721	710	687	616	547
Calcium required for gain (g/day)						
0.5 (1.1)	14	13	12	11	10	9
1.0 (2.2)	27	25	23	21	19	17
1.5 (3.3)	39	36	33	30	27	25

Body Weight in kg (lb)	200 (440)	250 (550)	300 (660)	350 (770)	400 (880)	450 (990)
2.0 (4.4)	52	47	43	39	35	32
2.5 (5.5)	64	59	53	48	43	38
Phosphorus required for gain (g/day)						
0.5 (1.1)	6	5	5	4	4	4
1.0 (2.2)	11	10	9	8	8	7
1.5 (3.3)	16	15	13	12	11	10
2.0 (4.4)	21	19	18	16	14	13
2.5 (5.5)	26	24	22	19	17	15
[a] Weight at small marbling, 533 kg (1,173); weight range, breed code Angus; see Table: Mean Nutrient Content of Feeds Commonly Used in Beef Cattle Diets [a] for abbreviations. The concentration of vitamin A in all diets for finishing steers and heifers is 2,200 IU/kg (1,000 IU/lb) dry diet.						
Adapted, with permission, from *Nutrient Requirements of Beef Cattle*, 2000, National Academy of Sciences, National Academy Press, Washington, DC.						

Nutrient Requirements of Growing Beef Bulls [a]

Body Weight in kg (lb)	300 (660)	400 (880)	500 (1,100)	600 (1,320)	700 (1,540)	800 (1,760)
Maintenance requirement						
NE_m (Mcal/day)	6.38	7.92	9.36	10.73	12.05	13.32
MP (g/day)	274	340	402	461	517	572
Calcium (g/day)	9	12	15	19	22	25
Phosphorus	7	10	12	14	17	19

Body Weight in kg (lb)	300 (660)	400 (880)	500 (1,100)	600 (1,320)	700 (1,540)	800 (1,760)
(g/day)						
Growth requirement (Average daily gain in kg [lb])						
NE_g required for gain (Mcal/day)						
0.5 (1.1)	1.72	2.13	2.52	2.89	3.25	3.59
1.0 (2.2)	3.68	4.56	5.39	6.18	6.94	7.67
1.5 (3.3)	5.74	7.12	8.42	9.65	10.83	11.97
2.0 (4.4)	7.87	9.76	11.54	13.23	14.85	16.41
2.5 (5.5)	10.05	12.47	14.74	16.90	18.97	20.97
MP required for gain (g/day)						
0.5 (1.1)	158	145	122	100	78	58
1.0 (2.2)	303	272	222	175	130	86
1.5 (3.3)	442	392	314	241	170	102
2.0 (4.4)	577	506	400	299	202	109
2.5 (5.5)	710	617	481	352	228	109
Calcium required for gain (g/day)						
0.5 (1.1)	12	10	9	7	6	4
1.0 (2.2)	23	19	16	12	9	6
1.5 (3.3)	33	27	22	17	12	7
2.0 (4.4)	43	35	28	21	14	8
2.5 (5.5)	53	43	34	25	16	8
Phosphorus required for						

Body Weight in kg (lb)	300 (660)	400 (880)	500 (1,100)	600 (1,320)	700 (1,540)	800 (1,760)
gain (g/day)						
0.5 (1.1)	5	4	3	3	2	2
1.0 (2.2)	9	8	6	5	4	2
1.5 (3.3)	13	11	9	7	5	3
2.0 (4.4)	18	14	11	8	6	3
2.5 (5.5)	22	17	14	10	6	3
[a] Weight at maturity, 890 kg (1,958 lb); breed code Angus; see Table: Mean Nutrient Content of Feeds Commonly Used in Beef Cattle Diets [a] for abbreviations. Vitamin A should be added at a level of 2,200 IU/kg (1,000 IU/lb) feed dry matter.						
Adapted, with permission, from *Nutrient Requirements of Beef Cattle*, 2000, National Academy of Sciences, National Academy Press, Washington, DC.						

Protein requirements currently are evaluated as metabolizable protein, which is interchangeable with absorbed protein. Metabolizable protein defines the protein more nearly as that which is available to the animal for maintenance and production. It is defined as the combination of the true protein absorbed by the intestine, supplied by microbial synthesized protein plus undegraded intake protein (UIP). The latter often has been called “bypass” protein.

Energy deficiency due to low feed intake or intake of poor quality feed is the most common deficiency that limits growth, development in heifers and bulls, milk production, and reproduction, with protein deficiency being the next most common. Protein deficiency of long duration eventually depresses appetite, with eventual weight loss and unthriftiness, even when ample energy is available.

Feedstuffs vary greatly in protein digestibility. For example, the protein of common grains and most protein supplements is ~75%–85% digestible, that of alfalfa hay ~70%, and that of grass hays usually 35%–50%. The protein of low-quality feeds, such as weathered grass hay, range grass, or cottonseed hulls, is digested poorly. Thus, even though total protein intake may appear to be adequate, metabolizable protein might be deficient.

A lack of protein in the diet adversely affects the microbial protein production in the rumen, which in turn reduces the utilization of low-

protein feeds. Thus, much of the potential nutritive value of roughages (especially energy) may be lost if protein levels are inadequate.

Urea and other sources of nonprotein nitrogen (NPN) are used commonly in commercial protein supplements to supply one-third or more of the total nitrogen requirement. Such products are broken down readily by the ruminal microbial protein to ammonia and then synthesized to high-quality microbial protein. The use of NPN needs available sources of ample phosphorus, trace minerals, sulfur, and soluble carbohydrates for the microbial synthesis of utilizable protein. The amount of crude protein (% N × 6.25) supplied by NPN must be stated on the feed tag accompanying commercial supplements. Toxicity is not a serious problem when urea is fed at recommended levels and mixed thoroughly with the other ingredients of the ration. However, rapid ingestion of urea at levels >20 g/100 lb (45 kg) body wt may lead to toxicity (see Nonprotein Nitrogen Poisoning). Several urea-molasses liquid supplements, containing as much as 10% urea, currently are self-fed to beef cattle. Caution should be exercised when cattle are started on such supplements.

Qualitatively, beef cattle require the same mineral elements as do dairy cattle; however, the relative quantities of the several minerals are different (see Table: Requirements and Maximum Tolerable Levels of Minerals for Beef Cattle [a]). The minerals most apt to be deficient in beef cattle diets are sodium (as salt), calcium, phosphorus, magnesium, zinc, copper, and selenium. In some areas, including the interior of the USA, iodine may be deficient in diets for pregnant cows; likewise, there are regional deficiencies (probably reflecting soil deficiencies) of several trace minerals, including copper, cobalt, and selenium. However, there are areas where some mineral elements (eg, selenium, molybdenum) are present at toxic levels. Attempts have been made to correct natural soil deficiencies for trace minerals by soil fertilization practices. Thus, it is implied that a beef producer needs to know the mineral and trace mineral content of the feedstuffs used in cattle rations. A general approach to prevent such deficiencies is to feed a commercial salt mineral mix developed for the geographic location of the herd.

Requirements and Maximum Tolerable Levels of Minerals for Beef Cattle [a]

	Requirement	

Mineral	Growing and Finishing	Gestation	Early Lactation	Ma Tol Lev
Chlorine (%)	—	—	—	—
Chromium (mg/kg)	—	—	—	1,0
Cobalt (mg/kg)	0.10	0.10	0.10	10
Copper (mg/kg)	10	10	10	100
Iodine (mg/kg)	0.50	0.50	0.50	50
Iron (mg/kg)	50	50	50	1,0
Magnesium (%)	0.10	0.12	0.20	0.4
Manganese (mg/kg)	20	40	40	1,0
Molybdenum (mg/kg)	—	—	—	5
Nickel (mg/kg)	—	—	—	50
Potassium (%)	0.60	0.60	0.70	3
Selenium (mg/kg)	0.10	0.10	0.10	2
Sodium (%)	0.06–0.08	0.06–0.08	0.10	—
Sulfur (%)	0.15	0.15	0.15	0.4
Zinc (mg/kg)	30	30	30	500

[a] Requirements for calcium and phosphorus are listed in the preceding nutrient requirement ta

Adapted, with permission, from *Nutrient Requirements of Beef Cattle*, 2000, National Academy Sciences, National Academy Press, Washington, DC.

The **salt** (NaCl) requirement for beef cattle is quite low (0.2% of the dry matter); however, there appears to be a satiety factor involved —almost all animals appear to seek out salt if it is not readily available. Range cattle may consume 2–2.5 lb (1 kg) salt/head/mo when forage is succulent but about half that amount when forage is mature and drier. When salt is added to a free-choice protein feed to limit intake, beef cows might consume >1 lb salt/day over long periods of time without adverse effects if they have plenty of drinking water. Signs of a salt deficiency are rather nonspecific and include pica and reduced feed intake, growth, and milk production.

Calcium is the most abundant mineral element in the body; ~98% functions as a structural component of bones and teeth. The remaining 2% is distributed in extracellular fluids and soft tissues and is involved in such vital functions as blood clotting, membrane permeability, muscle contraction, transmission of nerve impulses, cardiac regulation, secretion of certain hormones, and activation and stabilization of certain enzymes. Most roughages are relatively good sources of calcium. Cereal hays and silages and such crop residues are relatively low in calcium. Although leguminous roughages are excellent sources of calcium, even nonlegume roughages may supply adequate calcium for maintenance of beef cattle. When cattle are fed such roughages produced on low-calcium soils, or when finishing cattle are fed high-grain diets with limited nonlegume roughage, a calcium deficiency may develop. Because lactating beef cows do not produce nearly the amount of milk that dairy cattle do, their calcium requirement is much less. Nevertheless, it is sound management to provide a free-choice salt mineral mixture tailored to the environment and production class of the grazing cattle. Salt should always be mixed with mineral, because salt drives intake. Cows have almost zero "nutritional wisdom," ie, they do not seek out feedstuffs or minerals when they are deficient, with the exception being sodium, so adding mineral to the salt generally improves intake among cattle with free-choice access to the mineral mix. The total ration should provide a calcium:phosphorus ratio of 1.2 to 2:1, with cows at minimum of 1.2:1 and feedlot steers at minimum of 2:1. Wider ratios appear to be tolerated if the minimum requirements for each mineral element are met and if adequate vitamin D (exposure to sunlight) is available. Range cattle should be provided a mineral supplement that has as much or more phosphorus than calcium, because green forage is many times higher in calcium. Research has shown that intake among cattle receiving free-choice mineral mix is highly variable. One study showed that 14%–15% of cows with free-choice access to mineral in block or loose form consumed zero mineral. The only time cattle should be offered mineral free choice

is when they are grazing and no other feed is being fed. If cows are consuming any other feed, the salt and mineral should be mixed with the ration so all cattle will ingest the prescribed amount of mineral.

Approximately 80% of the **phosphorus** in the body is found in the bones and teeth, with the remainder distributed among the soft tissues. Phosphorus may be deficient in some beef cattle rations, because roughages often are low in phosphorus. Furthermore, as forage plants mature, their phosphorus content declines, making mature and weathered forages a poor source. Phosphorus has been described as the most prevalent mineral deficiency for grazing cattle worldwide. Most natural protein supplements are fairly good sources of phosphorus. Because adequate phosphorus is critical for optimal performance of beef cattle, including growth, reproduction, and lactation, a phosphorus supplementation program is recommended using either a free-choice mineral mixture or direct supplementation in the diet. In a phosphorus deficiency, reduced growth and efficiency of feed conversion, decreased appetite, impaired reproduction, reduced milk production, and weak, fragile bones can be expected. There does not appear to be any advantage to feeding more phosphorus than is recommended. Furthermore, feeding excess phosphorus contributes to increased environmental pollution. Good sources of supplemental phosphorus include steamed bone meal, mono- and dicalcium phosphate, defluorinated rock phosphate, and phosphoric acid. Corn co-products like corn gluten and distillers grains with solubles are also high in phosphorus. Because most grains are relatively good sources of phosphorus, feedlot cattle rarely suffer a phosphorus deficiency, although phytic acid chelation of phosphorus in grains may render up to one-half of it unavailable —especially for monogastric animals such as swine and poultry.

Magnesium maintains electrical potentials across nerve endings. In a deficiency, the lack of control of muscles is obvious. However, normally deficiencies are not anticipated. A magnesium deficiency in calves results in excitability, anorexia, hyperemia, convulsions, frothing at the mouth, and salivation, but such a condition is uncommon. Usually, a magnesium deficiency is seen in the spring in more mature grazing cattle under field conditions (ie, grass tetany, see Hypomagnesemic Tetany in Cattle and Sheep). The initial signs are nervousness, reduced feed intake, and muscular twitching about the face and ears. Animals are uncoordinated and walk with a stiff gait. In advanced stages, affected cows fall to the ground, convulse, and die shortly after. A blood sample from affected cows would show a serum magnesium level of <2 mg/dL, with a corresponding calcium deficiency. This condition is

sufficiently prevalent that many beef cow herd managers supplement in the spring with magnesium oxide at 28–56 g/head/day. Beef cows generally do not like magnesium oxide; dilution by mixing it with ground corn or incorporating it into a free-choice liquid supplement improves acceptability.

Potassium is the major cation in intracellular fluid and is important in acid-base balance; it is involved in regulation of osmotic pressure, water balance, muscle contractions, nerve impulse transmission, and several enzymatic reactions. Potassium deficiencies normally are not anticipated in cattle diets because most forages are good sources, containing 1%–4%. In fact, the high potassium content of spring pasture grass is one of the highest risk factors for grass tetany (see Hypomagnesemic Tetany in Cattle and Sheep). A potassium deficiency might be anticipated when diets extremely high in grain are fed (eg, in finishing cattle), because grains may contain <0.5% potassium. A marginal to deficient level of potassium in growing and finishing cattle results in decreased feed intake and rate of gain. However, this effect is subtle and probably would not be noticed other than by the very experienced cattle feeder. Body stores of potassium are small, and a deficiency may develop rapidly. It is good practice to supplement rations for growing and finishing cattle such that they will contain >0.6% potassium on a dry-matter basis.

Copper and **cobalt** deficiencies are likely more widespread than previously thought. Cobalt functions as a component of vitamin B_{12}. Cattle do not depend on dietary vitamin B_{12}, because ruminal microorganisms can synthesize it from dietary cobalt. In cattle, therefore, a cobalt deficiency is a relative vitamin B_{12} deficiency, and such cattle show weight loss, poor immune function, unthriftiness, fatty degeneration of the liver, and pale skin and mucosa. Copper functions as an essential component of many enzyme systems, including those that involve the production of blood components. Recommended levels of cobalt and copper should be provided in the diet, either by supplementation of the total mixed ration or as part of the free-choice mineral mix or supplemental mix.

Iodine is an integral part of thyroxine and, as such, is largely responsible for control of many metabolic functions. Typically, coastal regions subjected to iodine-carrying winds off the ocean have abundant supplies of iodine; however, in inland soils (in the USA, especially between the Allegheny and Rocky mountains), the soil generally does not have sufficient iodine to meet most livestock needs. Iodine requirements in cattle can be met adequately by feeding stabilized iodized salt.

Selenium is part of the enzyme glutathione peroxidase, which catalyzes the reduction of hydrogen peroxide and lipid hydroperoxides, thus preventing oxidative damage to the body tissues. White muscle disease in calves (see Nutritional Myodegeneration), characterized by degeneration and necrosis of skeletal and heart muscles, is the result of a selenium deficiency. Vitamin E plays a role in preventing such conditions. Other signs of a selenium deficiency include unthriftiness, weight loss, reduced immune response, and decreased reproductive performance. Selenium can be included in mineral mixes at a level up to 120 ppm so that cattle intake is 3 mg/head/day.

Although cattle probably have a metabolic requirement for all the known vitamins, dietary sources of vitamins C and K and the B-vitamin complex are not necessary in all but the very young. Vitamin K and the B vitamins are synthesized in sufficient amounts by the ruminal microflora, and vitamin C is synthesized in the tissues of all cattle. However, if rumen function is impaired, as by starvation, nutrient deficiencies, or excessive levels of antimicrobials, synthesis of these vitamins may be impaired.

Vitamin A can be synthesized from β-carotene contained in feedstuffs such as green forages and yellow corn. However, this ability varies among breeds; Holstein cattle perhaps are the most efficient converters of carotenes, whereas some of the beef breeds are much less efficient. Therefore, providing supplemental vitamin A to beef cattle should be considered. Vitamin A is one of the few vitamins that cattle store in their livers—as much as a 6-mo supply. Cattle on a diet deficient in vitamin A may not begin to show signs for several weeks. Newborn calves, which have small stores of vitamin A, depend on colostrum and milk to meet their needs. If the dam is fed a ration low in carotene or vitamin A during gestation (eg, in winter), severe deficiency signs may become apparent in the young suckling calf within 2–4 wk of birth, while the dam may appear healthy.

It is sound practice to provide 2–5 lb (1–2 kg) of early-cut, good-quality legume or grass hay in the daily ration of stocker cattle and pregnant cows to prevent vitamin A deficiency. Most commercial protein and mineral supplements are fortified with dry, stabilized vitamin A. The daily requirements for beef cattle appear to be ~5 mg of carotene or 2,000 IU of vitamin A/100 lb (45 kg) body wt; lactating cows may require twice this amount to maintain high vitamin levels in the milk.

Vitamin A deficiency under feedlot conditions can cause considerable loss to cattle feeders, especially if high-concentrate and corn silage rations low in carotene have been fed. Destruction

of carotene during hay storage or in the GI tract, or the failure of beef cattle to convert carotene to vitamin A efficiently, may increase the need for supplemental vitamin A. Growing and finishing steers and heifers fed low-carotene diets for several months require 2,200 IU of vitamin A/kg of air-dry ration. Commercial vitamin A supplements are not expensive and should be used when such rations are fed and any danger of a deficiency exists. An alternative way to supply supplemental vitamin A is by IM injection: studies show that an extremely high dose (6 million U) would be needed to supply adequate vitamin A for 7 mo. As with all vitamins and minerals, a steady supply in the diet is the ideal method for supplementation.

Vitamin D deficiency is comparatively rare in beef cattle, because they are usually outside in direct sunlight or fed sun-cured roughage. In northern latitudes during long winters, or in show calves kept in the barn or turned out only at night, a deficiency is possible. The ultraviolet rays of sunlight convert provitamin D found in the skin of animals (7-dehydrocholesterol) or in harvested plants (ergosterol) to active vitamin D. Direct exposure to sunlight, consumption of sun-cured feed, or supplementary vitamin D (300 IU/45 kg body wt) prevent a deficiency.

For the interrelationships of vitamin E and selenium in reproduction and in the etiology of various myopathies and the predisposition of a relative thiamine (vitamin B_1) deficiency, see Nutritional Myopathies in Ruminants and Pigs. (Also see Polioencephalomalacia.)