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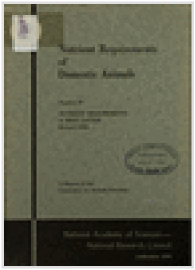

Nutrient Requirements of Beef Cattle: Revised 1958 (1958)

Pages
37

Size
6 x 9

ISBN
0309347580

Subcommittee on Beef Cattle Nutrition; Committee on Animal Nutrition; Agricultural Board; Division of Biology and Agriculture; National Research Council

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NUTRIENT REQUIREMENTS OF DOMESTIC ANIMALS

Number IV

NUTRIENT REQUIREMENTS

of

BEEF CATTLE

Revised 1958

A Report of the

N.R.C. COMMITTEE ON ANIMAL NUTRITION

Prepared by the

SUBCOMMITTEE ON BEEF CATTLE NUTRITION

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Publication 579

NATIONAL ACADEMY OF SCIENCES—NATIONAL RESEARCH COUNCIL

Washington, D. C.

1958

[Price $1.00]

4706
no. 4
908

Library of Congress Card Catalog Number *54-60841*

NUTRIENT REQUIREMENTS OF BEEF CATTLE

The first Subcommittee on Beef Cattle Nutrition of the National Research Council's Committee on Animal Nutrition was appointed in 1943 for purposes of preparing nutritional standards for beef cattle. The first report of the subcommittee was published by the National Research Council in 1945 and was entitled RECOMMENDED NUTRIENT ALLOWANCES FOR DOMESTIC ANIMALS. IV. RECOMMENDED NUTRIENT ALLOWANCES FOR BEEF CATTLE. A revised set of tables of Recommended Nutrient Allowances was published in December 1950.

New data have become available which have made it necessary to revise the tables again. Also, valuable suggestions for improving clarity and usefulness of the tables have been received from college personnel and those working in the feed industry. Attempts have been made to incorporate these suggestions into the revised edition.

In general, the same procedure has been followed in making this revision as was followed in compiling the information contained in the original publication. The committee has, however, attempted to evaluate both new and old data basing the recommendations on nutrient requirements rather than allowances, which in the past included margins of safety to compensate for variations in feed composition, environment, and possible losses of nutrients during storage or processing. No margins of safety have been included intentionally in the present report. These requirements will be further revised from time to time as new information of practical value becomes available on beef cattle nutrition.

The values presented in tables 1 and 2 are based on experimental results, and the methods of establishing many of these values are described briefly in the following paragraphs. Beef cattle rations computed on the basis of these requirements are expected to promote optimum liveweight gains in fattening cattle, continuous and rapid growth of young stock, and high percentage calf crops with heavy weaning weights in breeding herds. Most successful year-around production of beef cattle usually depends upon the degree of attainment reached in meeting their day-to-day nutrient requirements. Under-nutrition in cattle can be successful only for relatively short periods of time, such as the wintering of beef cows prior to going on grass in the spring.

Dietary requirements and feed composition tables can be of assistance in determining the adequacy of any particular ration with respect to the major nutritional factors. It is likely that not all the nutritional factors needed by beef cattle are listed and that new factors will be isolated and identified in the future. In bringing together the available information on nutrient requirements, the committee has become acutely aware of the inadequacies of quantitative data on many aspects of beef cattle nutrition. The committee is confident, however, that the information presented, when used intelligently as a guide in practical feeding problems, can contribute to the efficiency of beef cattle production.

The inclusion of brief descriptions of the more common nutritional deficiency diseases can serve as an aid in recognizing faulty nutrition in beef cattle. It is likely, however, that some of these conditions will seldom be seen under practical feeding conditions. On the other hand, it is hoped that, where such conditions do exist, the description and photographs will be of some assistance in their early recognition and treatment. It is further hoped that this report will be useful to those concerned with the formulation of beef rations and those concerned in the

TABLE 1

Daily Nutrient Requirements of Beef Cattle
(Based Upon Air-Dry Feed Containing 90 Per Cent Dry Matter)

Body weight	Av. daily gain[1]	Daily feed per animal	Daily nutrients per animal: Total protein	Digestible protein	TDN	DE[2]	Ca	P	Carotene	Vitamin A[3]
lb.	lb.	lb.	lb.	lb.	lb.	therms	gm.	gm.	mg.	IU x 1000
Fattening calves finished as short yearlings										
400	2.3	12	1.3	1.0	8.0	16	20	15	7	2.8
600	2.4	16	1.8	1.3	10.9	22	20	17	10	4.0
800	2.2	20	2.0	1.5	13.6	27	20	18	14	5.6
1000	2.2	22	2.2	1.6	15.0	30	20	20	17	6.8
Fattening yearling cattle										
600	2.4	18	1.8	1.4	11.7	23	20	17	10	4.0
800	2.8	22	2.2	1.6	14.3	29	20	20	14	5.6
1000	2.5	26	2.6	2.0	16.9	34	20	24	17	6.8
1100	2.3	27	2.7	2.0	17.6	35	20	25	19	7.6
Fattening two-year cattle										
800	2.8	24	2.4	1.8	14.9	30	20	22	14	5.6
1000	3.0	27	2.7	2.0	16.7	33	20	25	17	6.8
1200	2.6	29	2.9	2.2	18.0	36	20	26	20	8.0
Wintering weanling calves										
400	1.0	11	1.1	0.7	6.0	12	13	10	7	2.8
500	1.0	13	1.3	0.8	7.0	14	13	10	9	3.6
600	1.0	15	1.4	0.8	8.0	16	13	10	10	4.0
Wintering yearling cattle										
600	1.0	16	1.3	0.8	8.0	16	13	11	10	4.0
800	0.7	18	1.4	0.8	9.0	18	13	12	14	5.6
900	0.5	18	1.4	0.8	9.0	18	13	12	15	6.0
Wintering pregnant heifers										
700	1.5	20	1.5	0.9	10.0	20	15	14	28	11.2
900	0.8	18	1.4	0.8	9.0	18	13	12	36	14.4
1000	0.5	18	1.4	0.8	9.0	18	13	12	40	16.0
Wintering mature pregnant cows[4]										
800	1.5	22	1.6	1.0	11.0	22	16	15	32	12.8
1000	0.4	18	1.4	0.8	9.0	18	13	12	40	16.0
1200	0.0	18	1.4	0.8	9.0	18	13	12	48	19.2
Cows nursing calves, first 3-4 months postpartum										
900–1100	0.0	28	2.3	1.4	16.8	34	30	23	100	40.0
Normal growth heifers and steers										
400	1.6	12	1.4	0.8	7.0	14	16	11	7	2.8
600	1.4	16	1.5	0.9	8.5	17	15	12	10	4.0
800	1.2	19	1.5	0.9	9.5	19	15	13	14	5.6
1000	1.0	21	1.6	1.0	10.5	21	13	14	17	6.8

TABLE 1—*Continued*

Body weight	Av. daily gain[1]	Daily feed per animal	Daily nutrients per animal: Total protein	Digestible protein	TDN	DE[2]	Ca	P	Carotene	Vitamin A[3]
lb.	*lb.*	*lb.*	*lb.*	*lb.*	*lb.*	*therms*	*gm.*	*gm.*	*mg.*	*IU x 1000*
Bulls, growth and maintenance (moderate activity)										
600	2.3	16	2.0	1.2	10.1	20	21	15	36	14.4
1000	1.6	20	2.4	1.4	12.0	24	19	15	60	24.0
1400	1.0	24	2.4	1.4	14.2	28	17	16	84	33.6
1800	0.0	26	2.4	1.5	14.0	28	15	18	108	43.2

[1] Average daily gain for fattening cattle is based upon cattle receiving stilbestrol. Fattening cattle not receiving stilbestrol gain from 10 to 20 per cent slower than the indicated values.

[2] DE (digestible energy) was calculated on the assumption that one gram of TDN has 4.41 kcal. (large calorie) of digestible energy. New information suggested that the value of 4.41 is more accurate than the 4.45 value often used previously. DE may be converted to metabolizable energy by multiplying by 82 per cent. 1000 large calories equal one therm.

[3] Multiply figures in column by 1000. Vitamin A requirement computed on the basis of 1 mg. carotene equals 400 IU Vitamin A.

[4] Under some range conditions it may not be economically justifiable to feed pregnant cows during winter months at these levels of total feed and TDN. Short periods of moderate weight loss can be tolerated without serious effects.

manufacture of cattle rations and cattle feed supplemental mixtures, and that the report will be useful to people engaged in educational endeavors, such as county agricultural agents, high school agricultural teachers, feed men, and veterinarians who have limited library facilities and who are called upon to answer questions regarding nutritional problems of beef cattle.

Feed Capacity of Beef Cattle and Expected Liveweight Gains

Fattening cattle consume feeds in amounts (dairy air-dry basis) equal to 2.5 to 3.0 per cent of their live weight. Older cattle and more fleshy individuals consume less feed per unit of body weight than do younger animals carrying less condition. Fleshy beef bulls weighing in excess of 1800 pounds, for example, will consume feeds in amounts equal to about 1.5 per cent of their live weight, whereas thin steers less than two years of age will consume fully twice as much feed per unit live weight.

The weight gains given for different ages of fattening cattle (tables 1 and 2) may be obtained with good quality feeder steers fed to low-to-average choice slaughter condition. Both feed consumption and gains vary somewhat with the condition of cattle, with the palatability of feeds, with weather conditions, and with management practices. Weight gains are lower for fattening heifers than for steers of comparable grade and weight. The use of diethylstilbestrol in fattening cattle usually increases gains from 10 to 20 per cent, and this increase was taken into consideration in tables 1 and 2. The additional liveweight gain resulting from stilbestrol usage is usually made with only nominal increases in feed intake.

For wintering weanling calves, a pound daily gain often represents a desirable goal for producers. For cattle that will be finished the following season on concentrates plus pasture, the gains indicated under normal growth are applicable. The winter gains shown for yearling stocker cattle are practical for cattle that will be pastured through the subsequent season and sold as feeders.

With pregnant mature cows of the dominant beef breeds, a weight of not less than about 1050 pounds before calving is usually necessary to support consistently regular rebreeding and sufficient lactation to produce heavy calf weaning weights. The gains indicated in tables 1 and 2 depend upon the assumption that the cows

TABLE 2

NUTRIENT REQUIREMENTS OF BEEF CATTLE EXPRESSED AS PERCENTAGE COMPOSITION OF AIR-DRY RATIONS

Body weight	Av. daily gain[1]	Daily feed per animal	Percentage of ration or amount, per pound of feed							
			Total protein	Digestible protein	TDN	DE[2]	Ca	P	Carotene	Vitamin A[3]
lb.	*lb.*	*lb.*	%	%	%	*therms/lb.*[4]	%	%	*mg/lb.*	*IU/lb.*
Fattening calves finished as short yearlings										
400	2.3	12	11.0	8.2	67	1.33	0.37	0.28	0.6	240
600	2.4	16	11.0	8.2	68	1.36	0.28	0.23	0.6	240
800	2.2	20	10.0	7.5	68	1.36	0.22	0.20	0.7	280
1000	2.2	22	10.0	7.5	68	1.36	0.20	0.20	0.8	320
Fattening yearling cattle										
600	2.4	18	10.0	7.5	65	1.30	0.25	0.21	0.6	240
800	2.8	22	10.0	7.5	65	1.30	0.20	0.20	0.6	240
1000	2.5	26	10.0	7.5	65	1.30	0.17	0.20	0.7	280
1100	2.3	27	10.0	7.5	65	1.30	0.16	0.20	0.7	280
Fattening two-year cattle										
800	2.8	24	10.0	7.5	62	1.24	0.18	0.20	0.6	240
1000	3.0	27	10.0	7.5	62	1.24	0.16	0.20	0.6	240
1200	2.6	29	10.0	7.5	62	1.24	0.15	0.20	0.7	280
Wintering weanling calves										
400	1.0	11	10.3	6.2	55	1.10	0.26	0.20	0.6	240
500	1.0	13	10.3	6.2	54	1.08	0.22	0.17	0.7	280
600	1.0	15	9.1	5.5	53	1.05	0.19	0.15	0.7	280
Wintering yearling cattle										
600	1.0	16	8.3	5.0	50	1.00	0.18	0.15	0.6	240
800	0.7	18	7.5	4.5	50	1.00	0.16	0.15	0.8	320
900	0.5	18	7.5	4.5	50	1.00	0.16	0.15	0.8	320
Wintering pregnant heifers										
700	1.5	20	7.5	4.5	50	1.00	0.16	0.15	1.4	560
900	0.8	18	7.5	4.5	50	1.00	0.16	0.15	2.0	800
1000	0.5	18	7.5	4.5	50	1.00	0.16	0.15	2.2	880
Wintering mature pregnant cows[5]										
800	1.5	22	7.5	4.5	50	1.00	0.16	0.15	1.5	600
1000	0.4	18	7.5	4.5	50	1.00	0.16	0.15	2.2	880
1200	0.0	18	7.5	4.5	50	1.00	0.16	0.15	2.6	1040
Cows nursing calves, first 3-4 months postpartum										
900–1100	0.0	28	8.3	5.0	60	1.20	0.24	0.18	3.6	1440
Normal growth heifers and steers										
400	1.6	12	11.7	7.0	58	1.16	0.29	0.21	0.6	240
600	1.4	16	9.3	5.6	53	1.06	0.20	0.16	0.6	240
800	1.2	19	7.8	4.7	50	1.00	0.17	0.15	0.7	280
1000	1.0	21	7.8	4.7	50	1.00	0.14	0.15	0.8	320

TABLE 2—*Continued*

Body weight	Av. daily gain[1]	Daily feed per animal	Percentage of ration or amount, per pound of feed							
			Total protein	Digestible protein	TDN	DE[2]	Ca	P	Carotene	Vitamin A[3]
lb.	*lb.*	*lb.*	*%*	*%*	*%*	*therms/lb.*[4]	*%*	*%*	*mg/lb.*	*IU/lb.*
Bulls, growth and maintenance (moderate activity)										
600	2.3	16	12.5	7.5	63	1.26	0.29	0.21	2.2	880
1000	1.6	20	12.0	7.2	60	1.20	0.21	0.17	3.0	1200
1400	1.0	24	10.0	6.0	59	1.18	0.16	0.15	3.5	1400
1800	0.0	26	9.3	5.6	54	1.08	0.13	0.15	4.2	1680

[1] Average daily gain for fattening cattle is based upon cattle receiving stilbestrol. Fattening cattle not receiving stilbestrol gain from 10 to 20 per cent slower that the indicated values.

[2] Digestible energy (DE) was calculated on the assumption that one gram of TDN contains 4.41 kilocalories (kcal.) of DE. The formula for converting kcal. per gram to therms per pound is given on page 5. DE may be converted to metabolizable energy by multiplying by 82 per cent.

[3] Vitamin A requirement computed on the basis of 1 mg. carotene equals 400 IU Vitamin A.

[4] One therm equals 1000 kilocalories or large Calories, or 1,000,000 small calories (1,000,000 cal.).

[5] Under some range conditions it may not be economically justifiable to feed pregnant cows during winter months these levels of total feed and TDN. Short periods of moderate weight loss can be tolerated without serious effects.

are potentially of about this size and that differences in weight are largely due to condition. The daily gains are those necessary if the lighter weight cows are to attain about 1050 pounds by the end of a 150-day winter period preceding calving. Heavier fat cows or heifers can lose some weight in winter without forfeiting any of their productiveness, provided the ration is otherwise adequate. The data on requirements are calculated to meet the rates of gain shown.

The figures given for normal growth of heifers and steers follow closely the available data for beef heifers. Although steers are somewhat heavier than heifers at the same age, gain faster, and mature less rapidly, the data will apply reasonably well to steers without appreciable fattening. Likewise, the gains for bulls coincide with data on well bred beef bulls fed for normal growth and development.

Total Digestible Nutrients and Digestible Energy

The figures presented in tables 1 and 2 for total digestible nutrients (TDN) for growing and fattening beef cattle represent approximate minimal requirements and were computed from recent feeding experiments. Where chemical data on feed composition were lacking, average composition and digestibility values were relied upon. For fattening cattle, the minimum TDN requirements listed in table 2 can be increased to a maximum of 75 per cent when justified by favorable concentrate prices in relation to roughage prices.

Digestible energy (DE) requirements of beef cattle were computed from TDN data and included in tables 1 and 2. The formula used in computing digestible energy was as follows:

$$\text{Therms DE} = \frac{\text{lbs. TDN} \times 454\ \text{gm} \times 4.41\ \text{Kcal}}{1000\ \text{Kcal}}$$

This formula is based on the assumption that each gram of TDN has 4.41 kilocalories of digestible energy. Digestible energy requirements computed in this fashion are no more reliable than the TDN values listed. However, it was felt that these computed DE values should be included at this time with the hope of stimulating actual analytical DE evaluations of beef cattle feeds in future research, since DE evaluations can more easily be carried out and made more meaningful than TDN evaluations.

The TDN requirements for wintering pregnant cows and heifers are based upon feeding trial data which show none to 1.5 pounds daily gain on computed TDN intakes of 9 to 11 pounds daily for cows weighing 1000 to 1200 pounds. Many range men having cows carrying considerable condition do not feel that it is economical to feed sufficient feed to prevent some loss in weight. In such cases, feeding somewhat less than the requirements in tables 1 and 2 would be justified.

Lack of sufficient total feed (TDN or DE) is probably the most common deficiency in beef cattle feeding practice. In limited feeding on farms or overstocked ranges, low energy intake is common, the results being slowing or cessation of growth (including skeletal growth), loss of weight, failure to conceive, and increased mortality. Low feed intake also commonly results in increased mortality from eating of toxic plants and from lowered resistance to parasites and disease. Very commonly, however, under-feeding is complicated by concomitant shortage of protein and other nutrients.

Minimum Roughage and Maximum Fat Content in Fattening Rations

The minimum requirement for roughage is 0.5 to 0.8 pound for each 100 pounds live weight in fattening cattle. Cattle receiving a full feed of grain and less than this minimum requirement for roughage are subject to bloat and other digestive disturbances. In most cases it is desirable that the roughage be coarse and not finely ground, in order to achieve normal physiological activity of the gastrointestinal tract.

Feed intake is limited (1) by the bulk-handling capacity of the intestinal tract and (2) by the daily TDN intake of cattle. Comparison of fattening rations varying in bulk indicates that those containing 70 to 75 per cent concentrates are sufficiently concentrated to permit maximum TDN intake. More concentrated rations do not appear to result in greater TDN intakes except possibly for short periods.

The need for at least minimal amounts of roughage in cattle rations is recognized. The data presented in tables 1 and 2 are also applicable where maximum usage of roughage in beef cattle rations is desired, compatible with sufficient total feed capacity in the animal in supplying adequate TDN intakes, or satisfactory liveweight gains. Concentrate-to-roughage ratios falling between the range of 30:70 to 70:30 have been shown experimentally to be satisfactory in promoting liveweight gains in growing and fattening cattle. Sometimes as much as 80 per cent concentrates are included in fattening rations. Economic conditions dictate the choice of concentrate-to-roughage ratios.

Animal fats may at times be cheap enough to merit consideration as substitutes for standard energy feeds. The energy content of such fats is approximately 2.25 times that of carbonaceous feeds and thus only small amounts are required to substantially increase the energy content of cattle rations. Research has shown, however, that an ether extract (fat) content of over 10 per cent in the concentrate portion of beef cattle rations may produce deleterious effects. Extremely small amounts of fatty acids shown to be essential in other species of animals are likely to be essential for beef cattle; however, no requirements have thus far been established.

Protein and Non-Protein Nitrogen

Protein requirements in tables 1 and 2 are based upon minimal needs for optimum production. When protein feeds are in liberal supply and low in cost, the listed requirements can be greatly exceeded without toxicity and without sacrificing performance of animals. Protein requirements are expressed on the basis of both total and digestible protein in which the latter value is expressed as 60 per cent of the former for high roughage rations and 75 per cent for high concentrate rations. This relationship conforms with approximately average digestibility values as presented in table 3.

Feeding trials were used as the basis in computing the protein requirements for wintering and growing steers and heifers and for fattening cattle. The protein requirement figures for growth agree reasonably well with those calculated by Blaxter and Mitchell (1948). The requirements for fattening agree closely with a generalized curve derived by Guilbert and Loosli (1951).

Little work has been reported on the effect of protein level on quality and quantity of semen production in bulls. Larsen (1949) tentatively suggested a level of 2.0 pounds daily, or 7.5 to 8.0 per cent digestible protein, in the ration for bulls preceding and during moderate to heavy service.

Non-protein nitrogen from sources such as urea is converted to protein in the rumen of cattle under suitable feeding conditions. These conditions include ample phosphorus, trace minerals, sulfur, and a source of readily available carbohydrate in the cattle ration. The proteins thus synthesized in the rumen are available to the animal, and according to the evidence at least 33 per cent of the total protein requirement may be met in this way.

In cattle under farm and range conditions symptoms of protein deficiency and of energy deficiency often seem similar and at times occur together. The symptoms of protein shortage in beef cattle rations are poor growth, depressed appetite, reduced milk secretion, irregular estrus, and loss of weight.

MINERALS

Sodium and Chlorine (Salt)

Sodium and chlorine requirements for cattle are of the order of 1.5 grams of sodium and less than 5 grams of chlorine daily for young growing animals. The corresponding values for lactating cows are 11 and 15 grams. Salt is usually fed free-choice to cattle, in which case they often consume more than the above-listed requirements, especially where loose salt is fed in preference to block salt. Experiments with growing dairy heifers and lactating cows, however, resulted in fully as good results with block salt, even though smaller quantities were consumed than when the salt was fed loose. The salt requirement of full-fed cattle will be amply met by 0.5 per cent salt in the total ration. Salt deficiency results in abnormal appetites for salt. Prolonged deficiency will result in lack of appetite, unthrifty appearance, marked decrease in milk production, and loss of weight. Excessive salt intake can result in toxicity. However, the practice of controlling supplemental feed intake with large percentages of salt has proved relatively safe. As much as 2 pounds of salt can be consumed daily by cows without deleterious effects, provided animals have free access to an abundant supply of good quality drinking water.

Calcium and Phosphorus

Calcium and phosphorus requirements for growth and fattening of cattle as listed in tables 1 and 2 have been calculated upon the basis of body needs and needs for rumen microorganisms. For fattening animals, the body needs were estimated by assuming a maintenance requirement of 2 grams of phosphorus and 1 gram of calcium for each 100 grams of protein required for maintenance. The phosphorus content of the expected gain was calculated on the basis of 19.6 grams of phosphorus per pound of protein gain, and the calcium stored in the gain was assumed to be 1.7 times the phosphorus. New information on the needs of rumen microorganisms in promoting high rates of liveweight gains in cattle suggest minimum needs of 0.20 per cent phosphorus in fattening rations and 0.15 per cent phosphorus in other rations. These requirements are believed to be minimum and allow no margin of safety. In practice it may be wise to feed higher levels of phosphorus. Data on the availability of calcium and phosphorus in various feeds are meager and requirements are expressed in terms of gross amounts needed, with little consideration being given to availability.

Phosphorus deficiency in cattle feeds is widespread throughout the world, particularly in semi-arid regions, and is commonly associated with soils deficient in the element. Phosphorus content of plants generally decreases markedly with maturity, and deficiencies in cattle often occur in connection with subsistence for long periods of time on mature dried forage.

The earliest symptoms of phosphorus deficiency are lowered appetites, decreased blood phosphorus, and reduced rate of gain. Milk production falls off. Efficiency of feed utilization, particularly of protein, is depressed. These effects are followed by depraved appetite, with specific craving for bones. Depraved appetite may lead to excessive salt ingestion and, in the absence of bones, to the chewing of stones and wood and the eating of dirt. Carcass debris, if available, may be consumed and may result in a secondary disease caused by a toxin of *C. botulinum*, called loin disease and lamziekte and characterized by paralytic symptoms. Long-continued phosphorus privation results in bone changes, lameness, and stiffness of joints. Bone fractures may occur. Low phosphorus rickets in young animals, osteomalacia, osteoporosis, and osteitis fibrosa in adults are general names descriptive of the bone alterations.

In contrast with phosphorus, calcium deficiency in beef cattle is comparatively rare and mild and the symptoms are inconspicuous. When fattening calves are fed heavily on concentrates, with limited quantities of non-legume roughage, their calcium intake is insufficient for optimum gain and bone development. Dried mature range forage, if predominantly grasses, may contain less than required minimum quantities, and cereal straws are usually deficient in calcium. Severe privation may so deplete the bones of calcium and phosphorus that fractures may occur. The addition of calcium to a deficient ration for fattening calves increases the rate of gain, improves feed utilization, results in heavier bones with higher ash content and greater breaking strength, and enhances market grade.

Magnesium

The magnesium requirement of beef cattle has not been determined. The dairy calf, however, is known to require 0.6 gram of magnesium per 100 pounds body weight. Although "grass tetany" and "grass staggers" are sometimes attributed to magnesium deficiency, uncomplicated cases of deficiency have been produced only on purified diets or by prolonged feeding of calves on milk.

Potassium

Potassium requirements in rats, swine, and poultry are known to exceed sodium requirements in these species. Since forages commonly fed to cattle contain much more potassium than sodium, it seems unlikely that a deficiency would occur under most practical conditions.

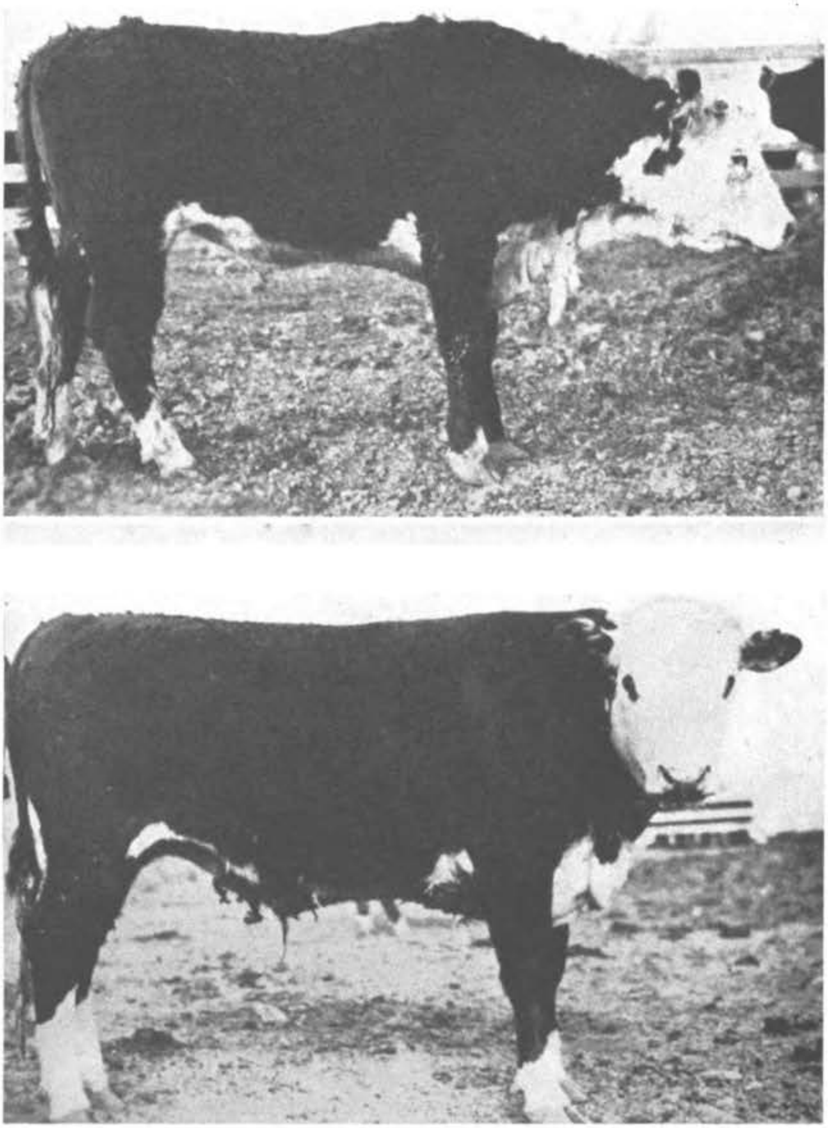

FIGURE 1.—Phosphorus deficiency in feed-lot cattle. The steer in the upper picture was fed a ration consisting of wet beet pulp, alfalfa hay, and beet molasses containing 0.12 per cent phosphorus. The steer shown in the lower picture received the same ration plus one-tenth pound daily of steamed bone meal, which brought the phosphorus content up to 0.18 per cent and provided an average total intake of 17.0 grams of phosphorus daily. (Idaho Agr. Expt. Sta. Photo by W. M. Beeson.)

Sulfur

Sulfur is required by the animal body in the form of sulfur-containing amino acids. It may be supplied in cattle rations, however, in either organic or inorganic form. When rations contain urea to partially supply the protein needs of cattle, either methionine or inorganic sulfur supplements such as sulfate or flowers of sulfur may prove beneficial. A number of studies, however, have shown no benefit from adding supplemental sulfur to practical rations containing as much as 40 per cent of the nitrogen in the form of urea, presumably due to adequate supplies of sulfur already present in the ration.

Iodine

Iodine requirements have been estimated, on the basis of a 1000-pound dairy cow producing 40 pounds of milk daily, to be 400 to 800 micrograms of iodine per day. The use of salt containing 0.01 per cent stabilized potassium iodide (0.0076 per cent iodine) will prevent symptoms of deficiency. Iodine deficiency is usually manifested by the production of dead or non-viable, goitrous calves. Occasional borderline cases may survive; in these, the moderate thyroid enlargement disappears in a few weeks.

Iron

Iron requirements of beef cattle are unknown, but levels in the feed are believed to be ample in most parts of the United States, since feeds often contain 40 to 400 milligrams of iron per pound. The iron requirement of cattle is believed to be less than that of swine. The swine requirement for iron has tentatively been set at 15 milligrams per pound of feed. No availability studies with iron for beef cattle have been reported.

Copper

Copper requirements of beef cattle appear to fall between 4 and 8 ppm of the total air-dry ration. When ration conditions are optimum, with low levels of molybdenum and sulfate, the copper requirement is probably no higher than 1.8 or 2.3 milligrams per pound. Copper deficiency can be prevented by adding 0.25 to 0.5 per cent copper sulfate to salt fed free-choice. Copper deficiency is an area disease and symptoms include depraved appetite, loss of condition, stunted growth, rough hair coat, and anemia. Diarrhea may vary from intermittent to severe. Estrus is surpressed. Young calves may have straight pasterns and stand forward on their toes. Animals may suddenly fall dead after little or no struggle, hence the term "falling disease" in Australia. Depigmentation of hair coat is common, but apparently may not be correlated with the severity of the disease. In addition to copper being an area disease, deficiencies have occurred in beef cattle kept on nurse cows for long periods beyond normal weaning age. Part of the syndrome of molybdenum toxicity, including change of hair color, is caused by interference with copper metabolism, and feeding additional copper will generally alleviate the symptoms. Excess copper is toxic. Less than toxic levels may depress liveweight gains in growing and fattening beef cattle.

Cobalt

Cobalt requirements of beef cattle are believed to fall between .07 and .10 milligram per 100 pounds body weight (approximately 0.03 to 0.05 milligram per pound of feed). These requirements are based upon analytical data on pas-

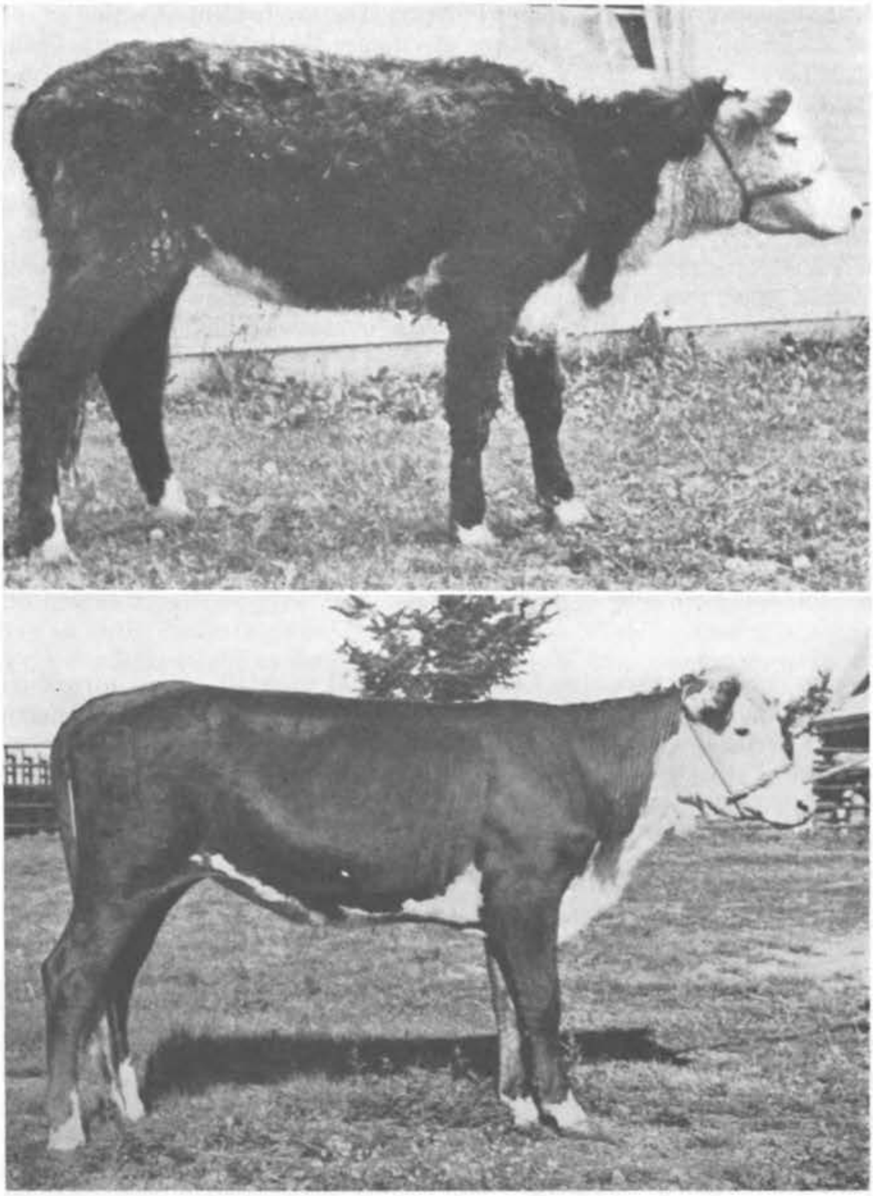

Figure 2.—Cobalt deficiency. The upper picture shows a heifer suffering from anemia and lack of appetite and exhibiting the characteristic roughness of hair coat. Administration of cobalt brought about remarkable recovery of appetite and disappearance of symptoms as shown in the lower picture. (Michigan Agr. Expt. Sta., East Lansing, Mich. Photo by C. F. Huffman.)

tures supporting healthy cattle free of cobalt deficiency symptoms. Cobalt, like copper, deficiency symptoms are mostly general in nature, being characterized by loss of appetite, weakness, emaciation, and eventual death. An anemia is common but the type does not appear to be constant. Cobalt administration in deficient animals brings about rapid recovery. The mechanism of action of cobalt appears to be the effect upon synthesis of vitamin B_{12} by rumen microorganisms, cobalt being an integral part of the vitamin molecule. Vitamin B_{12} injection will also relieve cobalt deficiency.

Manganese

Manganese requirements of beef cattle are uncertain but appear to be met with as little as 2.7 to 4.5 milligrams per pound in the air-dry ration. Since many roughages contain 22.5 to 67.5 milligrams per pound of manganese on a dry basis and grains other than corn contain 6.75 to 22.5 milligrams per pound, it seems unlikely that most beef cattle rations require manganese supplementation.

Zinc

Zinc requirements have not been established for beef cattle but, on the basis of its demonstrated needs in swine and laboratory animals, this mineral is probably a dietary essential. The likelihood of zinc deficiency in beef cattle appears remote since most forages contain between 4.5 and 45 milligrams per pound, which would supply adequate or excessive amounts in animal species where requirements have been determined.

Fluorine

Fluorine intakes at excessive levels are harmful to cattle. Certain rock phosphates must be defluorinated to make them safe for cattle feeding. Undefluorinated rock phosphate often contains 3.5 to 4.0 per cent of fluorine and when fed at a level of 1 per cent in the ration provides a toxic level. The harmful effects of fluorine over prolonged feeding to livestock are due to fluorine accumulation in the bones, which become thickened and softened, decreasing their breaking strength. Mottling of the enamel and erosion of the teeth may occur. Appetite is decreased and slow growth results. Fluorine is a cumulative poison and the toxic effects are not noticeable at first. Because of the accumulation of fluorine in the body under prolonged feeding, it is probably wise to exercise more care with breeding animals to be retained in the herd. A safe recommendation appears to be a level of not more than 2.93 milligrams per pound in the ration of cattle to be slaughtered and not more than 13.5 milligrams per pound for animals kept in the breeding herd for long periods of time.

Selenium

Selenium toxicity is an area problem and is not generally experienced. Chronic cases of selenium poisoning occur when cattle consume feeds containing 38.25 milligrams per pound of selenium for a sufficient period of time. At 1.35 to 1.8 milligrams per pound, however, there may be some accumulation in the tissues. Acute cases occur on 225 to 450 milligrams per pound. The symptoms are characterized by loss of appetite, loss of hair from the tail, sloughing of hoofs, lameness, and eventual death. Although arsenic has been shown to counteract the effects of selenium toxicity, there appears to be no practical method of treating other than removal of animals from the affected area.

Molybdenum

Recent research indicates that molybdenum is an essential mineral nutrient, being an integral part of important enzyme systems of the body. The requirement for beef cattle is unknown but probably is extremely small, since 10 to 20 ppm in forages results in toxic symptoms. The effect of toxic levels is an interference with copper metabolism, thus increasing the copper requirement, which results in typical copper deficiency symptoms. Recent work has shown that when feeds are high in sulfate, toxic symptoms are produced on lower levels of molybdenum and, conversely, higher levels of molybdenum can be tolerated with low levels of sulfate. One gram of copper sulfate per head daily will prevent and cure symptoms of molybdenum toxicity. Because beef cattle are extremely susceptible to molybdenum toxicity, which may be exaggerated by high sulfate levels, it is probably not advisable to supplement beef cattle rations with molybdenum under most conditions, pending more information on requirements.

Carotene and Vitamin A

Carotene, the precursor of physiologically active vitamin A, is found in many feeds commonly used in beef production. For purposes of comparison, one milligram of carotene is roughly equivalent to 400 international units (IU) of vitamin A. The requirements listed in tables 1 and 2 are expressed in terms of both carotene and vitamin A.

Levels of 1.4 to 1.7 milligrams of carotene per 100 pounds of live weight have proved adequate for normal growth. Beef cows during pregnancy require 3 to 4 milligrams of carotene per 100 pounds live weight in order to produce strong calves at birth. Lactating beef cows require about 10 milligrams of carotene per 100 pounds live weight to supply vitamin A needs of nursing calves during the first 3 to 4 months of age.

In meeting the day-to-day vitamin A requirements of beef cattle under practical feeding conditions, consideration should be given to (1) body stores of vitamin A as influenced by previous feeding and (2) carotene destruction in feeds during storage. Cattle store vitamin A and carotene in the liver and in body fat during times of abundant intake from pasture and other feeds. These storage reserves if sufficiently large may be used for limited periods of time in reducing or completely covering the day-to-day needs of cattle for carotene or vitamin A. On the other hand, the day-to-day needs of cattle for carotene or vitamin A may appear to be increased because of oxidative destruction of these materials in feeds during storage.

Vitamin A deficiency in cattle results in night blindness, muscular incoordination, staggering gait, and convulsive seizures probably caused by increased cerebrospinal fluid pressure. Total and permanent blindness in young animals results from stenosis of optic foramina and atrophy of optic nerves. Other localized paralysis may also occur. Excessive lacrimation rather than xerophthalmia usually occurs, the cornea of the eyes becomes keratinized and may upon infection develop ulceration. Severe diarrhea in young calves and intermittent diarrhea at advanced stages of deficiency in adults are characteristic. Cystic pituitary glands are common in deficient young animals. In fattening cattle, generalized edema or anasarca may occur with clinical symptoms of lameness in the hock and knee joints and swelling in the brisket area. Pulmonary complications culminating in pneumonia have been reported.

Vitamin A deficiency in bulls of breeding age leads to a decline in sexual activity. Spermatozoa decrease in numbers and motility, and there is a marked

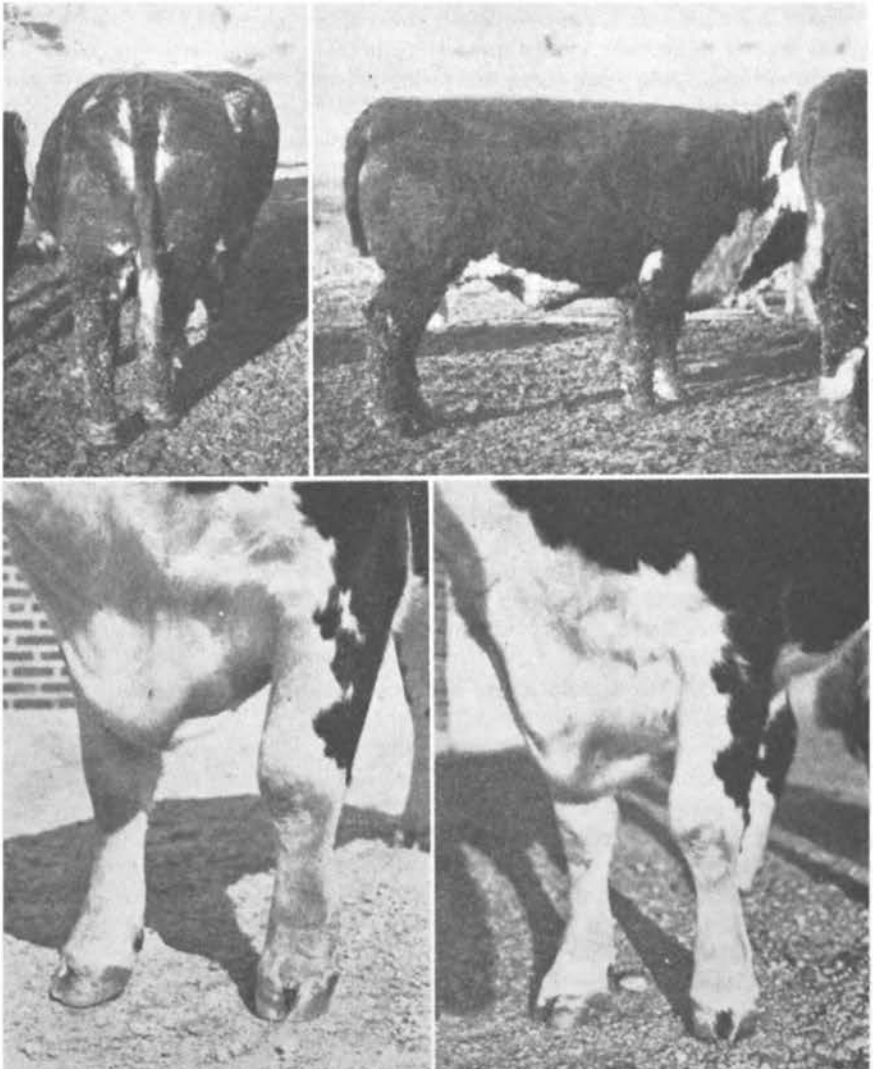

FIGURE 3.—Swelling (generalized edema, or anasarca) often develops in cattle suffering from vitamin-A deficiency. Deficiency under feed-lot conditions has caused considerable loss to cattle feeders and slaughterers. In the top pictures of feed-lot cattle note swollen legs, dry hair coat, and edema in the abdominal region. The lower left picture shows anasarca in an experimental case; the lower right shows the disappearance of swelling following vitamin-A therapy. (Photos by L. L. Madsen, Bureau of Animal Industry.)

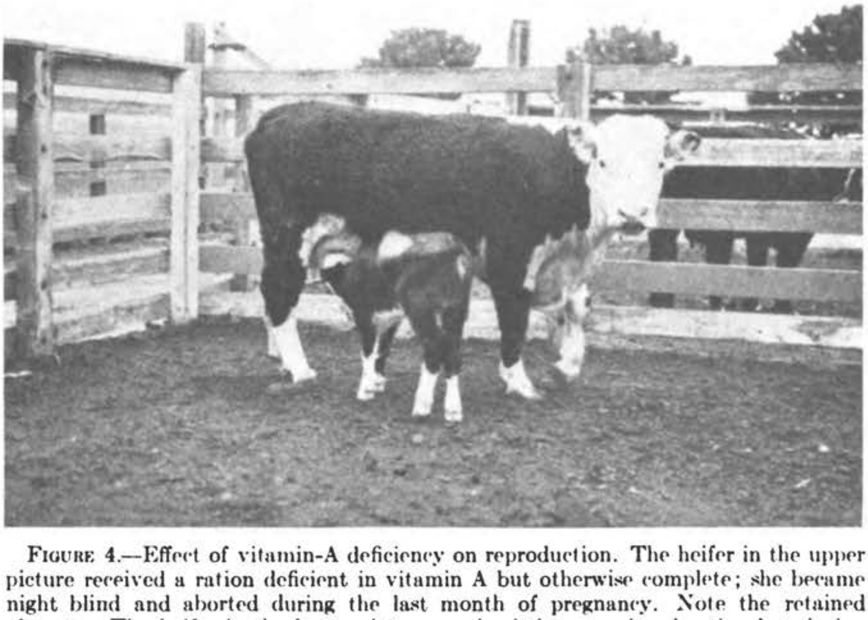

FIGURE 4.—Effect of vitamin-A deficiency on reproduction. The heifer in the upper picture received a ration deficient in vitamin A but otherwise complete; she became night blind and aborted during the last month of pregnancy. Note the retained placenta. The heifer in the lower picture received the same basal ration but during the latter part of the gestation period it was supplemented with 1 pound daily of dehydrated alfalfa meal containing about 50 mg. of carotene. A normal vigorous calf was produced. (Calif. Agr. Expt. Sta. Photo by H. R. Guilbert.)

FIGURE 5.—This cow developed rickets early in life when maintained on a vitamin-D deficient ration and not allowed exposure to direct sunlight. Note the bowed front legs and enlarged joints. (Photo by L. L. Madsen, Bureau of Animal Industry.)

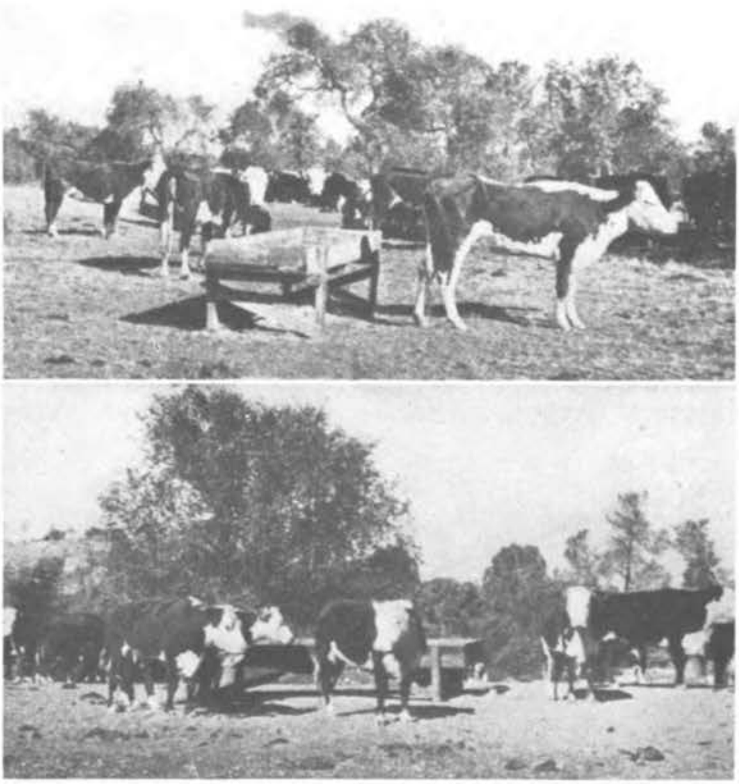

FIGURE 6.—Effect of protein deficiency and low energy intake on range cattle. The cows in the upper picture lost weight on dried range forage deficient in protein and low in phosphorus, were thin and weak after calving. Their calves weighed 386 pounds at weaning time, and they produced only a 61 per cent cattle crop the following year. The cows in the lower picture were on the same range but were fed sufficient cottonseed cake to meet their protein requirements. Barley was added as a source of additional energy after calving until new forage was available. Their calves weighed 481 pounds at weaning time and they produced a 91 per cent calf crop the following year. (San Joaquin Experimental Range, O'Neals, California. Photos by M. W. Talbot.)

increase in abnormal forms. In breeding cows, estrus may continue when vitamin A deficiency has advanced to the point where convulsions are common, but ability to become pregnant is impaired. Deficiency in the pregnant animal, if sufficiently severe, may result in abortion or birth at term of dead, weak, or blind calves. Vitamin A deficiency can be detected by carotene and vitamin A analysis of blood and liver tissue of cattle.

Vitamin D

The vitamin D requirement of beef cattle is estimated to be 300 IU per 100 pounds of live weight based upon experimental results with calves. Under usual conditions of management, beef cattle receive sufficient vitamin D from exposure to direct sunlight or from sun-cured hay.

Deficiency of vitamin D in calves reared under controlled experimental conditions results in rickets similar to that occurring in the young of other species of livestock. Clinical symptoms are usually preceded by a decrease in blood calcium and inorganic phosphorus. This is usually followed by poor appetite, decrease in growth rate, digestive disturbances, stiffness in gait, labored breathing, irritability, weakness, and occasionally tetany and convulsions. Later, enlargement of the joints, slight arching of the back, bowing of the legs, and erosion of the joint surfaces cause additional pain and difficulty in locomotion. Posterior paralysis may follow fracture of vertebrae. Symptoms develop more slowly in older animals. Work with dairy cattle has shown that vitamin D deficiency in the pregnant animal may result in dead, weak, or deformed calves at birth.

Vitamin E

The quantitative vitamin E (alpha-tocopherol) requirement of beef cattle has not been critically measured, but it is tentatively estimated to be less than 40 milligrams of alpha-tocopherol per 100-pound calf per day. Under most conditions, natural feedstuffs supply adequate quantities of alpha-tocopherol for adult cattle; however, muscular dystrophy in calves has been reported in certain geographical areas. The signs of alpha-tocopherol deficiency, termed muscular dystrophy or white muscle disease, appear in calves between the ages of 2 and 12 weeks. The most common signs of a deficiency are heart failure and paralysis varying in severity from a slight lameness to complete inability to stand. A dystrophic tongue often is seen in affected animals.

Intradermal injection of alpha-tocopherol has not proved as effective as oral administration. The most effective means of preventing losses of calves from vitamin E deficiency is supplementation of the ration of the pregnant cow and of the calf shortly after parturition with alpha-tocopherol. The incidence of losses from muscular dystrophy in affected areas has been lower among calves whose mothers received 2 or 3 pounds of grain mixture during the last 60 days of pregnancy.

B Vitamins and Vitamin K

Dietary requirements for B vitamins (thiamine, biotin, niacin, pantothenic acid, riboflavin, and vitamin B_{12}) have been demonstrated experimentally for the young calf during the first 8 weeks of life, prior to the development of a functioning rumen. These requirements in practice are usually adequately met by milk supplied the calf by the beef cow during early lactation. Following this early age, B vitamins appear to be synthesized in sufficient quantities in most feeding regimens by rumen bacterial fermentation, so that no dietary B vitamins need be supplied to cattle. Unusual feeding conditions, however, such as severe inadequacy of protein or other nutrients in the cattle ration, may impair rumen fermentation to such an extent that sufficient quantities of B vitamins for meeting the animal's needs will not be synthesized. Such deficiencies, if they occur, have not been clearly defined in beef cattle production.

Although vitamin K is synthesized in the rumen of cattle in adequate amounts under most feeding conditions, symptoms of inadequacy occur when the dicumarol content of hay is excessively high. Moldy sweet clover hay has been shown at times to be high in dicumarol, resulting in a bleeding syndrome through the body, called sweet clover poisoning or bleeding disease. Most effective treatment of this disease is administration of menadione (vitamin K_3) and removal of the offending feed from the cattle ration.

FIGURE 7.—Selenium toxicity in cow grazing on forage produced on alkali soil containing excessive selenium. Note emaciated condition, curvature of back and deformed hoofs resulting in abnormal stance. (Photo by H. F. Eppson, Wyoming Agricultural Experiment Station.)

Nutrient Needs of Rumen Microorganisms

It is recognized that rumen microorganisms must be supplied adequate nutrients in the cattle ration at all times, to promote satisfactory rumen function in the digestion of roughages and the synthesis of B vitamins and protein. These nutrients have been described in *in vitro* studies and include (1) energy, including small amounts of readily available energy such as sugars or starches, (2) ammonia-bearing ingredients such as proteins, urea, and ammonium salts, (3) major minerals, especially sodium, potassium, and phosphorus, (4) cobalt and possibly other trace minerals, and (5) unidentified factors found in certain natural feeds

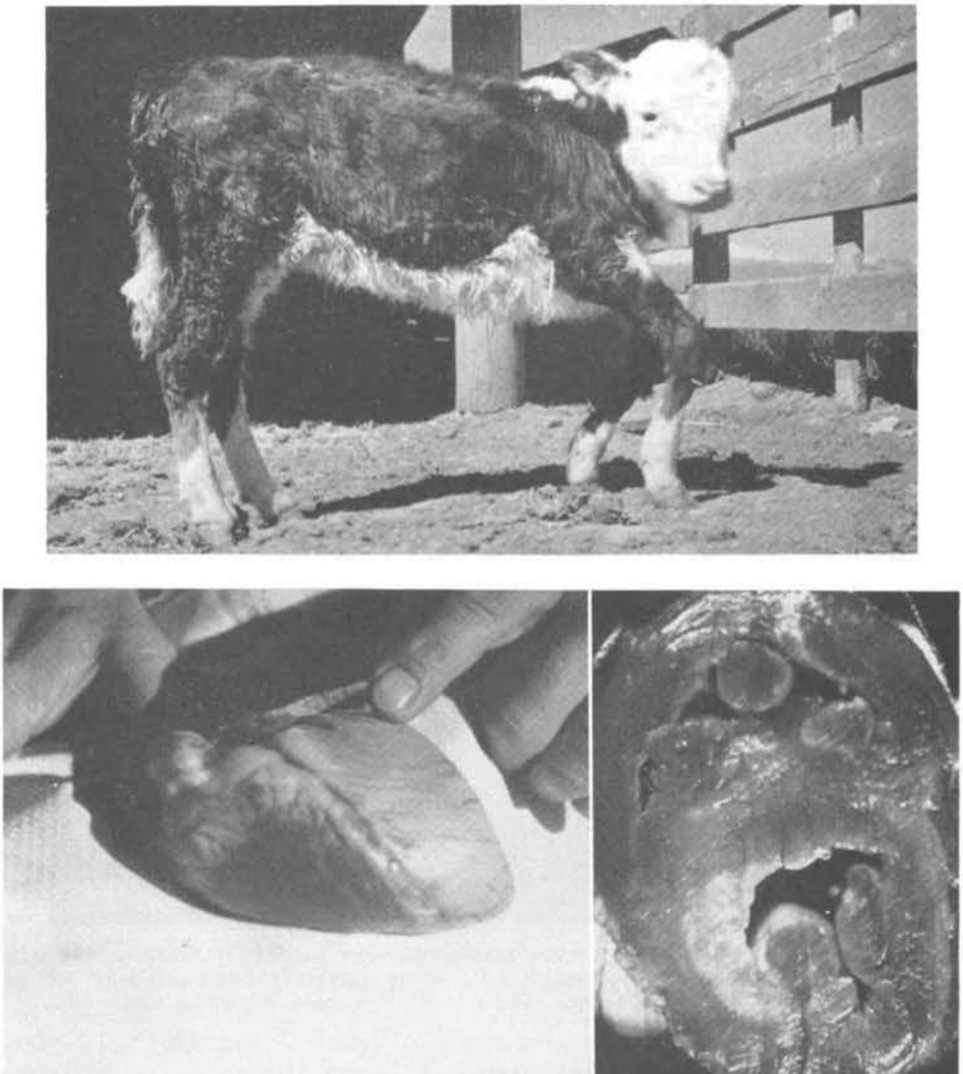

FIGURE 8.—White muscle disease in a calf about three months of age. Generalized weakness of muscles, lameness, and difficulty in locomotion can be seen in the upper photo. The lower photos show abnormal white areas in the heart muscles. (Photo by O. H. Muth, Oregon Agricultural Experiment Station.)

rich in protein or non-protein nitrogenous constituents. Since these nutrient needs of rumen microorganisms are approximately similar on a qualitative basis to the body nutrient needs of beef cattle, and both must be supplied simultaneously through the cattle ration, no attempt has been made to separate these requirements. Instead, both have been given consideration jointly in the above discussion and in the tables in listing the total needs for cattle. More experimental information is needed on the quantitative nutrient requirements of rumen microorganisms before separate requirements can be established.

Hormones and Other Accessory Ration Ingredients

Stilbestrol (diethylstilbestrol) is being used as a ration ingredient or as a skin implant for the majority of beef cattle being fattened in the United States at the present time. This material gives benefits in growing and fattening cattle. It is not recommended, however, for breeding stock. The most satisfactory feeding level for steers is 10 milligrams daily per 400- to 1200-pound animal, or 12 to 36 milligrams per animal when implanted. Stilbestrol feeding (10 milligrams daily per animal) may be successfully employed in fattening heifers; however, implantation of stilbestrol in fattening heifers requires further study before it can be recommended. Other hormone or hormone-like substances are being experimentally tested as agents for stimulating liveweight gain in growing and fattening beef cattle. Stilbestrol, although not a nutrient, brings about a more efficient conversion of nutrients in growing and fattening cattle and also stimulates liveweight gains materially. There is some evidence suggesting that stilbestrol usage may also influence protein and mineral requirements of cattle. However, these influences have not been quantitatively established at this time. In the tables, expected liveweight gains in fattening cattle have been increased by about 15 per cent in this revision over those listed in the previous revision because of widespread usage of stilbestrol in feeding practice.

Several broad spectrum antibiotics have shown some promise in dry lot feeding of cattle. These feed additives, when used, are usually fed at the rate of 10 milligrams daily per 100 pounds live weight or 80 milligrams per day for yearling or older cattle. Benefits are not always obtained, and variations in response are not fully understood but may relate to the disease level present.

Many other accessory ration ingredients are being experimentally tested and used to a limited extent in beef cattle feeding practice for purposes of stimulating liveweight gains and improving feed utilization. These include live rumen cultures, surface active agents, and arsenical compounds. Although some of these ingredients have at times appeared to improve overall feeding performance of cattle rations, favorable responses to date have not been sufficiently consistent to merit their usage in cattle feeding.

Composition of Feeds

Table 3 presents the composition of some of the more common cattle feeds, expressed in terms of those nutrients for which requirements are stated in tables 1 and 2.

The data are based, for the most part, upon recent analyses compiled jointly by the Subcommittees on Nutrient Requirements of Beef Cattle, Dairy Cattle, and Sheep, working in conjunction with the Committee on Feed Composition of the National Research Council. It is realized that individual samples may vary widely from the indicated averages because of such things as climate and soil

TABLE 3

AVERAGE COMPOSITION AND DIGESTIBLE NUTRIENTS

Feedstuff	Total dry matter	Protein	Dig. protein	TDN[1]	DE[2]	Calcium	Phos-phorus	Caro-tene
	%	%	%	%	therms/lb	%	%	mg/lb
Dry roughages								
Alfalfa hay, all analyses	90.5	15.3	10.9	50.7	1.02	1.47	0.24	8.2
Alfalfa hay, 1/10 to 1/2 bloom	90.5	15.4	11.2	51.4	1.04	1.47	0.24	20.3
Alfalfa hay, 3/4 to full bloom	90.5	14.1	10.2	50.3	1.02	1.22	0.22	8.5
Alfalfa hay, past bloom	90.5	12.9	9.3	47.7	0.96	1.10	0.20	3.3
Alfalfa meal, dehydrated	92.7	17.7	12.4	54.4	1.10	1.60	0.26	42.4
Alfalfa leaf meal, dehydrated	92.7	21.1	16.0	57.2	1.16	1.69	0.25	62.9
Barley hay	90.8	7.3	4.0	51.9	1.05	0.26	0.23	—
Barley straw	90.0	3.7	0.7	42.2	0.85	0.33	0.10	—
Birdsfoot trefoil hay	91.2	14.2	9.8	55.0	1.11	1.60	0.20	19.7
Bromegrass hay, all analyses	88.8	10.4	5.3	49.3	1.00	0.42	0.19	—
Clover hay, alsike, all analyses	88.9	12.1	8.1	53.2	1.07	1.15	0.23	—
Clover hay, crimson	89.5	14.2	9.8	48.9	0.99	1.23	0.24	—
Clover hay, Ladino	89.5	18.5	14.2	59.5	1.20	1.53	0.29	—
Clover hay, red, all analyses	88.3	12.0	7.2	51.8	1.05	1.28	0.20	7.3
Clover and mixed grass hay, high in clover	89.6	9.6	5.5	51.8	1.05	0.88	0.21	6.1
Clover and timothy hay, 30 to 50% clover	88.1	8.6	4.7	51.0	1.03	0.69	0.16	—
Corn cobs, ground	90.4	2.3	0.0	45.7	0.92	0.11	0.04	—
Corn fodder, medium, in water	82.6	6.8	3.3	53.9	1.09	0.25	0.14	1.8
Corn stover, medium, in water	80.3	5.8	2.0	45.5	0.92	0.48	0.08	—
Cowpea hay, all analyses	90.4	18.6	12.3	51.4	1.04	1.37	0.30	—
Kafir fodder, very dry	90.0	8.7	4.5	53.6	1.08	0.35	0.18	2.0
Kafir stover, very dry	90.0	5.5	1.9	51.3	1.04	0.54	0.09	1.1
Lespedeza hay, annual, before bloom	89.1	14.3	7.2	49.2	0.99	1.03	0.20	20.4
Lespedeza hay, annual, in bloom	89.1	13.0	6.4	46.4	0.94	1.00	0.19	—
Lespedeza hay, annual, after bloom	89.1	11.5	3.6	39.6	0.80	0.90	0.15	—
Mixed hay, good, less than 30% legumes	89.2	8.8	4.8	48.8	0.99	0.90	0.19	6.4
Oat hay	88.1	8.2	4.9	47.3	0.96	0.21	0.19	—
Oat straw	89.8	4.1	0.7	44.8	0.90	0.24	0.09	—
Orchard grass hay, good	88.7	8.1	4.2	49.7	1.00	0.27	0.18	—
Pea hay, field	89.3	14.9	10.6	55.1	1.11	1.22	0.25	—
Peanut hay, mowed	91.4	10.6	6 9	58.4	1.18	—	—	8.0
Prairie hay, western, cut in mid-season	91.3	6.0	2.0	45.1	0.91	0.33	0.12	9.1
Prairie hay, western, mature	91.9	4.4	0.9	43.7	0.88	0.36	0.08	3.6
Quack grass hay	89.0	6.9	2.5	40.3	0.81	—	—	—
Reed canary grass hay	91.1	7.7	4.9	45.1	0.91	0.33	0.16	—
Rye hay	91.3	6.7	2.4	42.5	0.86	—	0.18	—
Rye straw	92.8	3.5	0	42.2	0.85	0.26	0.09	—
Sorghum fodder, sweet, dry	88.9	6.2	3.3	52.4	1.06	0.34	0.14	1.1
Soybean hay, good, all analyses	88.1	14.6	9.8	48.6	0.98	1.10	0.22	13.6
Soybean hay, in bloom or before	88.0	16.7	12.0	52.4	1.06	1.29	0.34	—
Soybean hay, seed developing	88.0	14.6	9.8	48.2	0.97	1.24	0.25	13.6
Soybean hay, seed nearly ripe	88.0	15.2	10.8	54.9	1.11	0.96	0.31	3.0
Soybean straw	88.9	3.9	1.1	38.6	0.78	—	0.05	—

TABLE 3—*Continued*

Feedstuff	Total dry matter	Protein	Dig. protein	TDN[1]	DE[2]	Calcium	Phos-phorus	Caro-tene
	%	%	%	%	*therms/lb*	%	%	*mg/lb*
Dry roughages—*Continued*								
Sudan grass hay, all analyses	89.4	8.8	4.3	48.6	0.98	0.36	0.27	—
Timothy hay, all anaylses	89.0	6.6	3.0	49.1	0.99	0.35	0.14	4.4
Timothy hay, before bloom	89.0	9.7	6.1	56.6	1.14	—	—	9.2
Timothy hay, full bloom	89.0	6.4	3.2	51.1	1.03	—	0.20	4.2
Timothy hay, late seed	89.0	5.3	1.9	41.9	0.85	0.14	0.15	2.5
Timothy and clover hay, ¼ clover	88.8	7.9	4.0	49.8	1.01	0.58	0.15	—
Vetch and oat hay, over ½ vetch	87.6	11.9	8.4	50.7	1.02	0.76	0.27	—
Wheat hay	90.4	6.1	3.3	46.7	0.94	0.14	0.18	—
Wheat straw	92.6	3.9	0.3	40.6	0.82	0.15	0.07	—
Silages, roots, and tubers								
Alfalfa, not wilted, no preservative	24.7	4.1	2.6	13.5	0.27	0.35	0.08	15.1
Alfalfa, wilted	36.2	6.3	4.3	21.5	0.43	0.51	0.12	11.4
Alfalfa-molasses, not wilted	26.8	4.1	2.7	15.4	0.31	0.41	0.08	14.5
Beet top, sugar	31.6	3.8	2.5	14.9	0.30	0.31	0.07	5.1
Cabbage, entire	9.4	2.2	1.9	8.1	0.16	0.06	0.03	—
Carrots, roots	11.9	1.2	0.9	10.3	0.21	0.05	0.04	—
Clover, Ladino, and timothy	29.9	5.4	3.9	21.4	0.43	0.31	0.07	15.6
Corn, canning factory waste	22.4	2.0	1.1	16.1	0.33	—	—	—
Corn, dent, well matured, all analyses	27.6	2.3	1.2	18.3	0.37	0.10	0.07	5.8
Corn, dent, well matured, well eared	28.5	2.3	1.3	19.8	0.40	0.09	0.07	—
Corn, dent, well matured, fair in ears	26.3	2.1	1.1	17.2	0.35	0.09	0.06	—
Corn, dent, immature, before dough stage	20.3	1.8	0.9	12.9	0.26	0.11	0.07	—
Corn stover, mature ears removed	23.7	1.6	0.6	14.0	0.28	0.08	0.10	—
Corn and soybeans, well matured 30% or more soybeans	28.3	3.2	2.0	19.7	0.40	0.20	0.08	—
Grass silage, considerable legumes	25.6	3.6	2.0	15.5	0.31	—	—	17.1
Grass silage, some legumes	27.6	3.2	1.9	15.6	0.32	—	—	20.7
Grass silage, some legumes, molasses added	25.8	3.2	1.9	15.1	0.31	0.32	0.12	—
Grass silage wilted, molasses added	33.6	4.5	2.6	19.1	0.39	—	—	6.2
Mangels, roots	9.2	1.3	0.9	7.1	0.14	0.02	0.02	—
Oats, molasses added	32.0	2.7	1.4	16.9	0.34	0.10	0.09	17.7
Pea vine	24.5	3.2	1.9	14.0	0.30	0.32	0.06	21.0
Potatoes, tubers	21.2	2.2	1.3	17.4	0.35	0.01	0.05	—
Potato-alfalfa hay	35.9	5.3	3.3	21.1	0.43	—	—	—
Potato-mixed hay	33.7	3.8	2.2	21.6	0.44	—	—	—
Potato-corn meal	31.7	2.0	1.0	27.0	0.55	—	—	—
Rutabagas, roots	11.1	1.3	1.0	9.5	0.19	0.05	0.03	—
Sorghum, sweet	25.4	1.6	0.8	15.2	0.31	0.08	0.05	2.7
Soybean, not wilted	24.8	4.2	2.9	14.6	0.29	0.35	0.09	14.6
Sudan grass	25.7	2.2	1.5	14.4	0.29	0.11	0.04	—
Timothy, not wilted, no preservative	30.9	3.3	1.8	18.4	0.37	0.18	0.09	14.1
Timothy, not wilted, molasses added	30.0	3.1	1.6	17.1	0.35	0.16	0.08	—
Turnips	9.3	1.3	0.9	7.8	0.16	0.06	0.02	—

TABLE 3—*Continued*

Feedstuff	Total dry matter	Protein	Dig. protein	TDN[1]	DE[2]	Calcium	Phos-phorus	Caro-tene
	%	%	%	%	therms/lb	%	%	mg/lb
Concentrates								
Barley, excluding Pacific Coast	89.4	12.7	10.0	77.7	1.57	0.06	0.40	—
Barley, Pacific Coast	89.9	8.7	6.9	78.8	1.59	0.06	0.33	—
Beans, field or navy	90.0	22.9	20.2	78.7	1.59	0.15	0.57	—
Beet, pulp, dried	90.8	9.1	4.3	68.2	1.38	0.68	0.10	—
Beet pulp, molasses, dried	92.0	9.1	6.0	72.3	1.46	0.56	0.08	—
Beet pulp, wet	11.6	1.5	0.8	8.8	0.18	0.09	0.01	—
Blood meal	90.5	79.9	56.7	58.9	1.19	0.28	0.22	—
Blood flour	90.8	82.2	78.9	81.2	1.64	0.45	0.37	—
Bone meal, raw	93.2	26.2	18.1	18.1	0.37	22.14	10.35	—
Bone meal, steamed	95.2	12.1	—	—	—	28.98	13.59	—
Brewers dried grains	92.4	25.9	20.7	66.0	1.33	0.27	0.50	—
Buttermilk, dried	92.5	32.0	28.8	83.0	1.68	1.34	0.94	—
Citrus pulp, dried	90.1	6.6	5.2	78.2	1.58	1.96	0.12	—
Coconut oil meal, expeller	92.8	20.4	17.3	76.3	1.54	0.21	0.61	—
Coconut oil meal, solvent	91.7	21.3	18.1	68.3	1.38	0.17	0.61	—
Corn and cob meal	86.1	7.4	5.4	73.2	1.48	0.04	0.22	—
Corn, yellow dent, #2	85.0	8.7	6.7	80.1	1.62	0.02	0.27	1.3
Corn, flint	88.5	9.8	7.5	83.4	1.68	—	0.33	—
Corn distillers dried grains	92.3	27.1	19.8	82.7	1.67	0.09	0.37	1.4
Corn distillers dried grains, with solubles	91.9	27.2	19.9	81.0	1.64	0.17	0.68	1.7
Corn distillers dried solubles	93.1	26.9	21.3	80.2	1.62	0.35	1.37	0.3
Corn gluten feed	90.4	25.3	21.8	75.4	1.52	0.46	0.77	3.8
Corn gluten meal	90.7	42.9	36.5	79.9	1.61	0.16	0.40	7.4
Cottonseed, whole, pressed	92.4	28.0	20.2	58.6	1.18	0.17	0.64	—
Cottonseed feed	90.8	39.2	30.6	65.4	1.32	0.15	0.64	—
Cottonseed oil meal, expeller	92.7	41.4	34.4	73.4	1.48	0.18	1.15	—
Cottonseed oil meal, solvent	91.4	41.6	34.5	66.1	1.34	0.15	1.10	—
Fish meal, menhaden	92.2	61.3	49.7	67.0	1.35	5.49	2.81	—
Flaxseed screenings	91.4	15.8	8.8	58.5	1.18	0.37	0.43	—
Flaxseed screenings oil feed	91.3	24.1	13.5	54.6	1.10	0.44	0.63	—
Hominy feed, white	89.8	11.1	7.9	82.9	1.67	0.02	0.58	—
Hominy feed, yellow	90.7	11.1	7.9	83.7	1.69	0.05	0.52	3.1
Linseed feed	90.5	33.8	28.4	74.2	1.50	0.43	0.65	—
Linseed oil meal, expeller	90.9	35.3	30.7	76.3	1.54	0.44	0.89	—
Linseed oil meal, solvent	90.9	35.1	29.5	71.0	1.43	0.40	0.83	—
Meat scrap	93.5	53.4	43.8	65.4	1.32	7.9	4.03	—
Meat scrap, 50% protein	94.0	50.6	41.5	62.2	1.26	10.57	5.07	—
Milk, cow's	12.8	3.5	3.3	16.3	0.33	0.12	0.10	—
Milk, ewe's	19.2	6.5	6.2	26.2	0.53	0.21	0.12	—
Molasses, beet	76.0	6.7	3.5	59.6	1.20	0.16	0.03	—
Molasses, cane	74.5	3.2	7.0	54.9	1.11	0.89	0.08	—
Molasses, cane, dried	96.1	10.3	—	62.6	1.26	—	—	—
Oats, excluding Pacific Coast	90.2	12.0	9.4	70.1	1.42	0.09	0.33	—
Oats, Pacific Coast	91.2	9.0	7.0	72.2	1.46	—	—	—
Oats, rolled (oatmeal)	90.8	16.1	14.5	91.4	1.85	0.07	0.46	—
Oats groats, (hulled)	90.4	16.2	14.6	91.9	1.86	0.08	0.46	—
Orange pulp, dried	89.3	7.0	5.5	78.8	1.59	0.63	0.10	—
Oyster shell, ground	99.6	1.0	—	—	—	38.05	0.07	—

TABLE 3—*Continued*

Feedstuff	Total dry matter	Protein	Dig. protein	TDN[1]	DE[2]	Calcium	Phos-phorus	Caro-tene
	%	%	%	%	*therms/lb*	%	%	*mg/lb*
Concentrates—*Continued*								
Peanut oil meal, expeller	92.0	45.8	41.7	80.2	1.62	0.17	0.57	—
Peanut oil meal, solvent	91.5	47.4	43.1	74.3	1.50	0.20	0.65	—
Potato meal, dried	90.3	5.9	2.1	65.1	1.32	—	—	—
Rape seed	90.5	20.4	17.3	117.1	2.37	—	—	—
Rice bran	90.6	13.5	9.2	71.0	1.43	0.06	1.82	—
Rice polishings	89.9	11.8	9.0	83.0	1.68	0.04	1.42	—
Rye grain	89.5	12.6	10.0	76.5	1.55	0.10	0.33	—
Rye distillers dried grains	93.0	22.4	13.4	60.2	1.22	0.13	0.41	—
Rye middlings	89.8	17.1	13.0	71.4	1.44	0.06	0.63	—
Safflower oil meal, expeller	90.6	19.7	15.8	48.4	0.98	0.23	0.71	—
Safflower oil meal, with hulls	93.2	23.7	19.0	51.5	1.04	—	—	—
Safflower oil meal, without hulls	91.1	38.4	33.8	64.4	1.30	0.31	0.58	—
Safflower seed	93.1	16.3	13.0	82.4	1.66	—	—	—
Skim milk, dried	93.9	33.5	30.2	80.3	1.62	1.26	1.03	—
Sorghum, Kafir	89.8	11.0	8.9	81.6	1.65	0.03	0.31	—
Sorghum, milo	89.0	10.9	8.5	79.4	1.60	0.03	0.28	—
Sorghum, milo, head chops	89.6	9.2	7.0	74.3	1.50	0.14	0.26	—
Soybeans	90.0	37.9	33.7	87.6	1.77	0.25	0.59	—
Soybean oil meal, expeller	89.7	43.8	36.8	77.0	1.56	0.27	0.63	—
Soybean oil meal, solvent	89.3	45.8	42.1	77.2	1.56	0.32	0.67	—
Sweet potato meal	90.2	4.9	0.7	72.7	1.47	0.15	0.14	32.2
Tankage, digester	92.1	59.8	50.8	66.1	1.34	5.94	3.17	—
Tankage, digester, with bone	94.1	49.6	42.2	64.7	1.31	10.97	5.14	—
Wheat, hard, winter	89.4	13.5	11.3	79.6	1.61	0.05	0.42	—
Wheat, hard, spring	90.1	15.8	13.3	80.7	1.63	0.04	0.40	—
Wheat, soft, winter	89.2	10.2	8.6	80.1	1.62	—	0.29	—
Wheat, soft, Pacific Coast	89.1	9.9	8.3	79.9	1.61	—	—	—
Wheat bran	89.1	16.0	13.0	65.9	1.33	0.14	1.17	1.2
Wheat flour middlings	89.8	18.4	16.2	78.2	1.58	0.11	0.76	—
Wheat germ oil meal	89.7	27.3	22.9	84.1	1.70	0.07	1.06	3.0
Wheat screenings, good grade	90.4	13.9	10.0	68.7	1.39	0.44	0.39	—
Wheat standard middlings	89.7	17.2	14.3	76.9	1.55	0.15	0.91	1.4
Whey, dried	93.5	13.1	11.8	78.4	1.58	0.87	0.79	—
Yeast, brewers dried	93.4	44.6	38.4	72.4	1.46	0.13	1.43	—
Yeast, torula, dried	93.3	48.3	41.5	69.9	1.41	0.57	1.68	—

[1] In calculating the values for total digestible nutrients, no digestion coefficients for a few feedstuffs were available, or the data were inadequate. In those instances the digestion coefficients for comparable feedstuffs were used.

[2] DE (digestible energy) may be converted to metabolizable energy by multiplying by 82 per cent.

The Committee on Animal Nutrition is indebted to Professor F. B. Morrison for the use of data from the 22nd Edition of *Feeds and Feeding* on the composition of roughages, silages, and cereals presented in this table. The data on the composition of by-product feeds were supplied by the Committee on Feed Composition of the National Research Council (NRC Pub. No. 449, 1956). The digestion coefficients used in calculating the digestible protein and TDN were also taken with Professor Morrison's permission from the 22nd Edition of *Feeds and Feeding*. These are based in part on the extensive compilation of digestion coefficients in *Feeds of the World* (W. Va. Agr. Expt. Sta., 1947), which was prepared by Dr. B. H. Schneider at the request of the Committee on Animal Nutrition

TABLE 4

COMPOSITION OF CALCIUM AND PHOSPHORUS SUPPLEMENTS

Mineral supplement	Calcium		Phosphorus		Fluorine
	%	gm/lb.	%	gm/lb.	%
Bone meal, raw, feeding	22.7	103	10.1	46	0.030
Bone meal, special steamed	28.7	130	13.9	63	—
Bone meal, steamed	30.0	136	13.9	63	0.037
Defluorinated phosphate rock a*	21.0	95	9.0	41	0.150 or less
Defluorinated phosphate rock b*	29.0	132	13.0	59	0.150
Defluorinated superphosphate	28.3	128	12.3	56	0.150
Dicalcium phosphate	26.5	120	20.5	93	0.050
Disodium phosphate	—	—	8.6	39	—
Limestone (high calcium)	38.3	174	—	—	—
Monocalcium phosphate	16.0	72	24.0	109	0.050
Monosodium phosphate	—	—	22.4	102	—
Oyster shell flour	36.9	167	—	—	—
Spent bone black	22.0	100	13.1	59	—

* Because of the limited number of products on the market, figures are given for two types of defluorinated rock which are being produced for livestock feeding.

where the feed was produced, crop variety, and storage conditions. Therefore, the values given should be used with judgment, often in conjunction with more specific information on the feed at hand. Table 4 gives the composition of calcium and phosphorus supplements.

Average carotene analyses are less reliable than those for other nutrients, not only because of sample variation but also because carotene is unstable in all samples. It decreases rapidly through oxidation during direct exposure to sunlight or to high temperatures. In feeds high in moisture, enzyme action causes destruction. Carotene is relatively stable in most feeds during storage at low temperature

TABLE 5

ESTIMATED CAROTENE CONTENT OF FEEDS IN RELATION TO APPEARANCE AND METHODS OF CONSERVATION[1]

Feedstuff	Carotene
	mg/lb
Fresh green legumes and grasses, immature	15 to 40
Dehydrated alfalfa meal, fresh, dehydrated without field curing, very bright green color[2]	110 to 135
Dehydrated alfalfa meal after considerable time in storage, bright green color	50 to 70
Alfalfa leaf meal, bright green color	60 to 80
Legume hays, including alfalfa, very quickly cured with minimum sun exposure, bright green color, leafy	35 to 40
Legume hays, including alfalfa, good green color, leafy	18 to 27
Legume hays, including alfalfa, partly bleached, moderate amount of green color	9 to 14
Legume hays including alfalfa, badly bleached or discolored, traces of green color	4 to 8
Non-legume hays, including timothy, cereal, and prairie hays, well cured, good green color	9 to 14
Non-legume hays, average quality, bleached, some green color	4 to 8
Legume silage	20 to 30
Green silage	5 to 20
Corn and sorghum silages, medium to good green color	2 to 10
Grains, mill feeds, protein concentrates, and byproduct concentrates, except yellow corn and its byproducts	.01 to 0.2

[1] This table was prepared by the late H. R. Guilbert, Davis, California.
[2] Green color is not uniformly indicative of high carotene content.

or where the feed is treated with a suitable anti-oxidant. The best practical guide, aside from carotene analysis, is the degree of green color present in forages. In visual estimates, the data in table 5 may be used as a general guide.

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