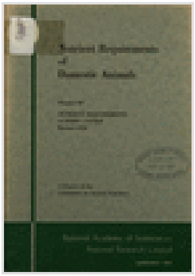

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NUTRIENT REQUIREMENTS OF DOMESTIC ANIMALS

Number III
NUTRIENT REQUIREMENTS
of
DAIRY CATTLE
Revised 1956

A Report of the
COMMITTEE ON ANIMAL NUTRITION
Prepared by the
SUBCOMMITTEE ON DAIRY CATTLE NUTRITION

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C. F. HUFFMAN — J. C. SHAW

Agricultural Board
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FOREWORD

This report on NUTRIENT REQUIREMENTS OF DAIRY CATTLE is the second revision of the report originally published in August 1945 as RECOMMENDED NUTRIENT ALLOWANCES FOR DAIRY CATTLE. The first revision was published in April 1950. In the second revision, new information developed since publication of previous editions has been incorporated.

The Committee on Animal Nutrition has recently emphasized the continuing need for research work on quantitative nutrient requirements of domestic animals, leading to more precise feeding standards. In changing the title of this series of reports from "recommended nutrient allowances" to "nutrient requirements" of domestic animals, the committee has recognized the desirability of expressing feeding standards in more precise terms than was done in the recommended allowances.

The revised report on the nutrient requirements of dairy cattle was prepared by the Subcommittee on Dairy Cattle Nutrition of the Committee on Animal Nutrition. The subcommittee is composed of members who have made a specialty of dairy cattle nutrition. The committee believes that the principle of using groups of especially qualified experts has resulted in the development of standards with a high degree of reliability, leading to the wide application of these standards in agricultural and commercial practice.

Whenever new experimental evidence is sufficiently well established, these reports will be revised and brought up to date.

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NUTRIENT REQUIREMENTS OF DAIRY CATTLE

The values presented as nutrient requirements of dairy cattle are considered to be adequate for "normal" growth, reproduction, and milk production, with feeds of average composition and as used in farm practice. The requirements listed in tables 1 and 2 are lower for certain nutrients than the values published as allowances in 1950. These reductions, especially for total digestible nutrients, calcium, phosphorus, and vitamin D, represent the elimination of recognized margins of safety above the actual requirements. In using the present standards, it may be desirable, therefore, to supply slightly larger quantities of the nutrients than those tabulated in order to allow for variability in feed composition.

Data available on requirements for the several functions are somewhat inadequate and there is need for continued investigation under controlled conditions and with more animals under practical farm conditions.

The amounts of nutrients required per day differ among individual animals, depending upon the rate of growth, size, and nervous temperament. A careful study of feed intakes (111) showed that growing Jersey cattle consumed approximately the same amounts of feed each day as Holstein cattle of the same body weight. Furthermore, large and small breeds of cattle thrive on rations similar in ingredients and nutrient content. From these considerations it is evident that the same values can be used for calculating the nutrient intakes of both large and small breeds of dairy cattle.

Nutrient requirements for growth and milk production are adequately considered in tables 1 and 2. With respect to reproduction, Becker *et al.* (15) found that the average changes in body weight of Jersey cows due to combined weights of the fetus, fluids, fetal membranes, and increased size of the uterus amounted to 43 pounds at 210 days of gestation, 75 pounds at 240 days, 110 pounds at 270 days, and 122 pounds at term. These results agree with earlier publications, which also showed that weight increases are 60 to 100 per cent greater in the larger breeds of dairy cattle than in Jerseys. The relationship between milk yield and increases in weight of the developing fetus during lactation is shown in figure 1.

High producing cows are underfed and decrease in body weight for the first 6 to 10 weeks of lactation. This loss can be recovered during later lactation and the dry period if sufficient amounts of a well balanced ration are fed to allow nutrients for the developing fetus and weight gains of the cow, as specified in table 1. Adequate feeding will minimize weight losses and sustain higher milk production.

Validation of Requirements

Digestible Protein

Because of high prices and recurrent shortages of protein, an effort has been made to define levels of protein intake which will prevent excessive wastage of this nutrient but which insure that a deficiency does not limit growth, milk production, or reproduction. The requirements (tables 1 and 2) for growth are slightly higher for young animals than Morrison's Standard but are lower for animals approaching maturity. These amounts appear to be adequate on the basis of the studies of Fredericksen (55), Ritzman and Colovos (113), and Lofgreen *et al.* (91).

The intakes of digestible protein for young dairy calves represent the amounts generally consumed when whole milk is fed, and they are considered satisfactory for normal growth. The minimum requirements have not been determined. Too little protein results in retarded growth and inefficient use of nutrients.

For maintenance, the value of 0.6 pound of digestible protein for 1000 pounds live weight, as suggested by Haecker (60) and by Hills *et al.* (68) was used as a base, and the amounts for other weights were calculated at the same rate per unit of weight to the $\frac{3}{4}$ power. Most of the published data show that an extra allowance for milk production of at least 125 per cent of the protein in the milk is needed under conditions of good feeding practice. This amount may not be fully adequate with low quality feeds. The present standard furnishes, above maintenance, approximately 135 per cent of the protein in the milk. It should

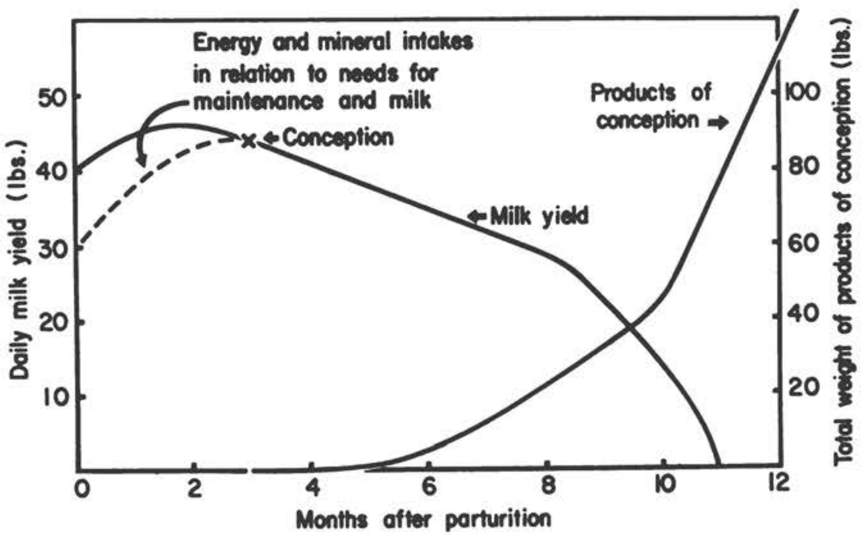

FIGURE 1

Relationship between milk production and fetal development in Jersey cows. Physiological underfeeding and weight loss occurs during the first 6 to 10 weeks, but these losses are recovered later if feed intakes are adequate.

be recognized that under certain conditions it may be advantageous to feed more protein than shown in table 1 and that no deleterious effects would result from much larger intakes. It has been demonstrated that urea and other simple nitrogen compounds can be used by growing dairy cattle (52, 63) and milking cows (116) to replace up to 25 per cent of the protein in the ration (112).

Total Digestible Nutrients

Although net energy values appear to be more accurate than total digestible nutrients when comparing roughages with concentrates for productive purposes, information is not available on the requirements of animals and the value of feeds. Variations in productive energy values suggest that unrecognized factors may be involved. Further research is needed to resolve this important problem. A limited energy supply more frequently retards the growth of dairy cattle and lowers milk production than does a deficiency of any other nutrient. In practice the tendency often is to overfeed protein and underfeed energy. The requirements

TABLE 1

Daily Nutrient Requirements of Dairy Cattle
(Based on air-dry feed containing 90 per cent dry matter)

Body wgt.	Daily gain: Small breeds	Daily gain: Large breeds	Daily nutrients per animal[1]: Feed	Protein	Digestible protein	TDN	DE[2]	Ca	P	Carotene	Vitamin D
lb	*lb*	*lb*	*lb*	*lb*	*lb*	*lb*	*therm*	*gm*	*gm*	*mg*	*IU*
			Normal growth of dairy heifers								
50	0.5	—	0.9	0.31	0.20	1.0	2.0	4	3	2[3]	150
100	1.0	0.8	2.0	0.62	0.40	2.0	4.0	7	6	4	300
150	1.3	1.4	4.0	0.78	0.50	3.0	6.1	12	10	6	450
200	1.4	1.6	6.0	0.94	0.60	4.0	8.1	13	10	8	600
400	1.2	1.8	11.0	1.25	0.80	6.5	13.1	13	12	16	[4]
600	0.8	1.4	15.0	1.33	0.85	8.5	17.1	13	12	24	—
800	1.1	1.2	19.0	1.40	0.90	10.0	20.2	13	12	32	—
1000	—	1.3	22.0	1.48	0.95	11.0	22.2	12	12	40	—
1200	—	1.2	24.0	1.56	1.00	12.0	24.2	12	12	48	—
			Maintenance of mature cows[5]								
800	—	—	12	0.95	0.50	5.8	11.7	6	6	32	[4]
1000	—	—	14	1.13	0.60	7.0	14.1	8	8	40	—
1200	—	—	16	1.32	0.70	8.2	16.6	10	10	48	—
1400	—	—	19	1.51	0.80	9.4	19.0	11	11	56	—
1600	—	—	21	1.64	0.87	10.5	21.2	12	12	64	—
			Reproduction (add to maintenance during last 2 to 3 months)								
—	2.0	2.0	8.0	1.13	0.60	6.0	12.1	8	7	30	[4]
			Lactation (add to maintenance for each pound of milk)								
—	—	3.0% fat	—	0.062	0.040	0.28	0.57	1	0.7	[6]	[6]
—	—	4.0% fat	—	0.070	0.045	0.32	0.65	1	0.7	—	—
—	—	5.0% fat	—	0.078	0.050	0.37	0.75	1	0.7	—	—
—	—	6.0% fat	—	0.086	0.055	0.42	0.85	1	0.7	—	—
			Maintenance of breeding bulls								
1200	—	—	18	1.56	1.00	10.3	20.8	10	10	48	—
1600	—	—	22	1.87	1.20	12.9	26.1	12	12	64	—
2000	—	—	27	2.20	1.45	15.6	31.5	16	16	80	—
2400	—	—	31	2.50	1.60	18.2	36.8	19	19	96	—

[1] Thiamine, riboflavin, niacin, pyridoxine, pantothenic acid, folic acid, vitamin B_{12}, and vitamin K are synthesized by bacteria in the rumen, and it appears that adequate amounts of these vitamins are furnished by a combination of rumen synthesis and natural feedstuffs. Manganese, magnesium, iron, copper, and cobalt are essential, and the amounts needed are discussed in the text.

[2] DE (digestible energy) was calculated on the assumption that one gram of TDN has 4.45 kcal. of digestible energy, a value based largely on the extensive summary of published data made by B. H. Schneider. DE may be converted to metabolizable energy by multiplying by 82 per cent.

[3] Calves should receive colostrum the first few days after birth, as a source of vitamin A and other essential factors.

[4] While vitamin D is known to be required, the data are inadequate to warrant specific figures for older growing animals and for maintenance, reproduction, and lactation.

[5] When calculating the intakes for lactating heifers that are still growing, it is recommended that the figure for growth rather than maintenance be used.

[6] When adequate amounts of vitamins A and D are fed for normal reproduction, extra amounts will not stimulate milk production but will increase the vitamin content of the milk.

of growing dairy cattle for total digestible nutrients are based on the data of Eckles and Gullickson (46), the normal intake data of the Missouri Station (111) and the data of Morrison (105). The requirements for maintenance are slightly lower than the Haecker standard (60), in line with the policy of listing the

TABLE 2

NUTRIENT CONTENT OF RATIONS FOR DAIRY CATTLE
(Based on air-dry feed containing 90 per cent dry matter)

Body wgt.	Average age		Per cent of ration or amount per pound of feed								
	Small breeds	Large breeds	Total daily	Feed % of wgt.	Digestible protein	TDN	DE[1]	Ca	P	Carotene	Vitamin D
lb	*months*	*months*	*lb*	%	%	%	*therms/lb*	%	%	*mg/lb*	*IU/lb*
					Normal growth of dairy heifers						
50	Birth	—	0.9	1.6	22.0	110	2.22	0.98	0.73	—	170
100	2.3	0.6	2.0	2.0	20.0	100	2.02	0.77	0.66	2.0	150
150	3.7	2.0	4.0	2.7	12.5	75	1.52	0.66	0.44	1.5	110
200	4.8	3.1	6.0	3.0	10.0	67	1.35	0.48	0.40	1.3	100
400	10.0	6.7	11.0	2.8	7.3	59	1.19	0.26	0.30	1.5	—
600	17.2	10.8	15.0	2.7	5.7	57	1.15	0.19	0.22	1.6	—
800	28.0	16.0	19.0	2.5	4.7	53	1.07	0.15	0.15	1.7	—
1000	—	22.0	22.0	2.2	4.3	50	1.01	0.13	0.13	1.8	—
1200	—	36.0	24.0	2.0	4.2	50	1.01	0.12	0.12	2.0	—
					Maintenance of mature cows						
800	—	—	0.12	1.8	3.6	50	1.01	0.12	0.12	2.3	—
1000	—	—	0.14	1.6	3.7	50	1.01	0.12	0.12	2.5	—
1200	—	—	0.16	1.5	3.9	50	1.01	0.12	0.12	2.7	—
1400	—	—	0.19	1.4	3.8	50	1.01	0.12	0.12	2.7	—
1600	—	—	0.21	1.3	3.8	50	1.01	0.12	0.12	2.8	—
					Lactating cows						
—	—	—	—	—	6.5	60	1.21	0.30	0.25	1.2	—
					Maintenance of breeding bulls						
1200	—	—	18	1.5	5.6	58	1.17	0.12	0.12	2.7	—
1600	—	—	22	1.4	5.5	58	1.17	0.13	0.13	2.9	—
2000	—	—	27	1.3	5.4	58	1.17	0.13	0.13	3.0	—
2400	—	—	31	1.3	5.2	58	1.17	0.14	0.14	3.1	—

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

minimum requirements without a margin of safety. Maintenance requirements for grazing cows may be appreciably higher than the values shown. It is desirable to feed somewhat more than the amounts suggested to thin cows. For young cows in the first or second lactations an extra allowance above that for maintenance and milk production should be provided to allow for growth. During the last 2 to 3 months of the gestation period liberal amounts of feed should be allowed in order to fit the cow for the coming lactation. The nutrients for milk production will give satisfactory production under usual conditions, but at times feeding more than the above amounts of energy may result in larger milk yields as indicated by the report of Jensen *et al.* (79). The values for bulls were found to maintain body weight and breeding efficiency (32).

The values in table 1 are minimum requirements. With dairy cattle under farm conditions the energy and protein allowances should be increased 10 to 15 per cent in order to provide for variability in feed composition.

Minerals

The essential mineral elements required by dairy cattle are: sodium, chlorine, calcium, phosphorus, magnesium, potassium, sulfur, iodine, cobalt, copper, manganese, iron, and probably zinc. These mineral elements are needed for bone formation and as constituents of the compounds, such as proteins and lipids, which make up the muscles, organs, blood cells, and other soft tissues of the body. They are concerned in the maintenance of osmotic relationships and acid-base equilibria and exert characteristic effects on the irritability of muscles and nerves.

Salt (NaCl). Babcock (3) recommended an allowance of 21 gm. (0.75 oz.) of salt for maintenance of a 1000-pound cow, plus an additional 9 gm. (0.3 oz.) for each 10 pounds of milk produced. Smith and Aines (125) found that 15 gm. (0.5 oz.) of salt per day was insufficient for milking cows and that 60 gm. (2.1 oz.) daily was ample for the level of milk production of the cows used (average 14,000 pounds of milk yearly). These investigators tentatively concluded that cows used in this study required approximately 1 ounce of salt per head daily in addition to that found in natural feeds. Sodium is more likely to be deficient than chlorine. Smith *et al.* (126) reported that cows consumed more loose than block salt. The lower intakes as block salt were adequate to meet the needs for lactation.

Calcium. Theiler *et al.* (129) obtained fair growth in heifers fed a ration containing 5 gm. of calcium daily. Converse (36) selected low-calcium timothy hay and then limited the amount of hay fed daily, bringing the calcium intake to 6 and 7 gm. per day for Jersey and Holstein heifers from 6 to 18 months of age. These amounts of calcium (0.12 to 0.14 per cent of the dry matter of the ration) were sufficient for almost normal growth but were inadequate for gestation when continued to first calving. Converse concluded that the calcium requirement for growth appeared to be 0.14 per cent of the total dry matter in the ration, and 0.16 per cent for gestation and lactation. These results indicate that dairy cattle make efficient use of calcium. Efficient use of dietary calcium by calves fed milk as the principal part of the ration was also observed by Duncan and Huffman (42) who reported 62 to 65 per cent retention of ingested calcium in two calves fed the basal ration and 62 to 75 per cent retention when large amounts of vitamin D were added. Hughes and Cave (76) found that two calves retained 63 per cent of dietary calcium on a whole milk ration. Blackwood *et al.* (20) reported that in their first experiment 8 calves retained 73 and 76 per cent of the calcium intake when fed raw and pasteurized milk, respectively, and in the second experiment 87 and 86 per cent. Similar results were reported by Blaxter and Wood (26). Both calcium and phosphorus storages were linearly related to the amount of milk ingested, and at the highest level (about 2.5 times maintenance intake) 92 per cent of the calcium and 80 per cent of the phosphorus were retained. Using the slaughter method, Ellenberger *et al.* (48) reported that calves weighing 109 pounds at birth contained 673 gm. calcium, while the calves slaughtered at about 1 year of age contained 2630 gm. or an average retention of 5.4 gm. daily.

Comar *et al.* (35) and Visek *et al.* (133) reported that the calcium requirement for maintenance varied from 5.2 to 10.6 gm. with a mean of about 8 gm. per 1000 pounds of body weight, compared with the 10 gm. in general use.

Each pound of milk contains on the average about 0.54 gm. of calcium. From the studies by Forbes *et al.* (53) it has become recognized that high producing cows are usually in negative balance during early lactation. The deficit is made up later in lactation and during the dry period. Ellenberger *et al.* (48) obtained liberal storage of calcium and phosphorus in an Ayrshire cow that produced 11,254 pounds of milk and received an average of 45 gm. calcium and 60 gm. phosphorus per day. This amounts to an intake of 1.1 gm. of calcium per pound of milk above maintenance on the basis of 10 gm. calcium a day for maintenance. Hart *et al.* (64) found that daily intakes of 25 to 28 gm. calcium and 28 gm. of phosphorus maintained good bones in cows producing 10,000 to 12,000 pounds of milk annually. Huffman *et al.* (75) presented data showing that, when not in early stages of lactation, liberally milking cows store calcium when fed low-calcium rations. A reappraisal of these data indicates that, when 8.0 gm. per 1000 pounds of body weight are allowed for maintenance, 1 gm. of calcium per pound of milk above maintenance is adequate for liberally milking cows.

Some of the heifers used by Converse (36) in studying the calcium requirement for growth were continued through several lactations on a very low calcium intake. One cow produced 30,489 pounds of milk in 3 lactations. This animal consumed 19,768 gm. of calcium during this time, including 2 dry periods. It is interesting that 87 per cent of the feed calcium was in the milk. Using 8.0 gm. of calcium per 1000 pounds of body weight for maintenance, most of the cows used by Converse received less than 1 gm. of dietary calcium per pound of milk.

Milk fever in cows is not due to a calcium deficiency in the ration, but to a disturbance in metabolism manifested by a marked drop in blood plasma calcium. Boda and Cole (30) found that the feeding of a low-calcium, high-phosphorus diet (Ca:P ratio of 1:3.3) during the last month of the dry period effectively prevented milk fever. Massive doses of vitamin D postpartum will also prevent milk fever (67) as is discussed later.

Phosphorus. Archibald and Bennett (2) in balance studies with dairy heifers observed larger phosphorus retentions with an intake of 3.25 gm. than of 1.8 gm. of the element per 100 pounds of body weight, but stated that heifers can make average growth on rations supplying 1.8 gm. of phosphorus daily per 100 pounds of body weight during the first year, 1.7 gm. during the second year, and 1.2 gm. during the third year of life. In a long-time experiment Huffman *et al.* (74) found that heifers receiving an average of 7.9 gm. of phosphorus daily from 3 to 18 months of age gained 432 pounds, while a group supplemented with bone meal so that they received 15.3 gm. of phosphorus daily gained 498 pounds on the average during the same period. The low-phosphorus group received 10 to 12 gm. of phosphorus daily from 18 to 24 months of age and prior to calving, which appeared adequate. These animals retained 3.6 to 5.8 gm. of phosphorus daily (87). According to Eckles *et al.* (47) about 8 gm. of phosphorus per day were insufficient to maintain normal plasma inorganic phosphorus values in heifers weighing 800 to 1100 pounds.

Lofgreen *et al.* (90) using casein labeled with P^{32} found the "true" digestibility of phosphorus fed to two calves to be 92 per cent. The endogenous fecal phosphorus values were 4.3 and 4.2 mg. per kg. of body weight, which may indicate a low maintenance requirement for phosphorus by the calf. Kleiber *et al.* (84) using P^{32} studied phosphorus metabolism in two cows producing about 22 pounds of milk per day. One cow, fed 37.1 gm. of phosphorus daily, excreted 32.5 gm. in the feces, of which 14 gm. was endogenous phosphorus. The apparent digestibility was 12 per cent and true digestibility 50 per cent. The other cow was fed 12.2 gm. of phosphorus daily. The fecal phosphorus was 14.5 gm. and endogenous fecal phosphorus 10.1 gm. per day. The "true" digestibility was 64 per cent. The maintenance requirement of the cow appears to be about 1 gm. per 100 pounds of body weight. According to Huffman *et al.* (73) the phosphorus requirement for milk production ranged from 0.5 to 0.7 gm. of feed phosphorus per pound of milk above maintenance. The requirement as shown in table 1 is 0.7 gm. of phosphorus per pound of milk above maintenance. Seventeen grams of phosphorus daily during the dry period prior to calving is suggested.

Magnesium. Several investigators have found that whole milk supplemented with iron, copper, manganese, and vitamin D is an inadequate ration for calves and that tetany results. Huffman *et al.* (72) showed that 30 to 40 mg. of magnesium per kilogram of body weight was required daily to maintain normal plasma magnesium values when magnesium oxide was used as a supplement to whole milk. When 2 pounds of corn were added as a supplement, normal plasma magnesium values were maintained on magnesium intakes of 12 to 15 mg. per kilogram of body weight. When 1 to 2 pounds of alfalfa were fed as a supplement, 10 to 12 mg. of magnesium per kilogram of body weight maintained normal plasma magnesium values. Alfalfa ash, however, failed to maintain normal magnesium values with intakes of 30 to 40 mg. of magnesium per kilogram of body weight. These results suggest that an unidentified organic factor present in corn and other feeds aids in magnesium utilization. The factor in corn gluten meal that affects utilization of dietary magnesium is removed in the water soluble fraction (66). Thomas and Okamoto (130) also reported that calves fed whole milk showed hypomagnesemia but were normal when given about 50 mg. of magnesium per kilogram of body weight. Calves receiving mineralized vitamin D milk plus ample magnesium died at 6 to 12 months of age. Blaxter *et al.* (24, 25) studied the symptoms of magnesium deficiency and magnesium requirements of calves, using a purified ration low in magnesium with casein the only milk product. The age of calves at termination of the experiment was 50 to 120 days. Tetanic convulsions occurred in calves after 30 per cent of total magnesium had been depleted from their bodies. For optimum magnesium retention, about 20 mg. per kilogram of body weight appeared to be needed. The calves used by Blaxter and Rook made very little weight gain, which probably accounts for their lower requirements and suggests that the diet may not have been complete. The magnesium requirement of 10 to 12 mg. per kilogram of body weight suggested by Huffman *et al.* appears satisfactory when a small amount of alfalfa hay supplements whole milk.

Iodine. The lack of iodine is recognized as the principal cause of goiter in newborn calves (82). The goiter areas are found primarily around the Great Lakes and westward to the Pacfic coast. In these regions iodine supplements have been shown to be necessary. The use of iodized salt containing 0.015 per cent iodine incorporated at a 1 per cent level of the grain ration has proved effective. When iodized salt is stabilized to retard loss of iodine, a product containing 0.0076 per cent iodine (0.01 per cent potassium iodide) will probably provide the needed iodine supplementation (56). The use of stabilized iodine is recommended as a supplement to the ration of pregnant cows on farms where goiter has been known to occur among newborn calves (71).

Cobalt. Cobalt deficiency among ruminants (16) has been referred to by different names in various regions of the world. Filmer and Underwood (51) in 1934 fractionated limonite which had proved effective in curing "bush sickness" and found cobalt in the active fraction. Lines (89) and Marston (97) in 1935 also identified cobalt deficiency. Cobalt deficiency was first observed in the United States by Neal and Ahmann (108) and Becker and Gaddum (13) in 1937. It has since been recognized among cattle in many states of the United States.

The discovery that vitamin B_{12} contained cobalt brought about a new approach as to how this element is utilized in ruminants. As was pointed out by Marston (98), the rumen bacteria use cobalt in the synthesis of vitamin B_{12}. This is the most important function of cobalt in ruminant nutrition.

The cobalt requirement of growing and milking cattle is not known. Filmer and Underwood (51) found that 0.3 to 1.0 mg. per day was effective in curing cobalt deficiency in cattle. The usual recommendation of mixing 1 ounce of cobalt sulfate or its equivalent with 100 pounds of salt is an effective supplement to local feeds in most areas.

Other minerals. Iron and copper are necessary for hemoglobin formation. Thomas *et al.* (131) found that calves born with normal hemoglobin levels showed a decline until 30 to 70 days of age, then a gradual increase in hemoglobin. Iron supplementation maintained normal hemoglobin. The calves were fed a ration consisting of milk, grain, and alfalfa hay. The iron requirement of cattle appears to be supplied ordinarily by that present in common feeds.

It appears that Neal *et al.* (109) in 1931 were the first to suggest that a deficiency of copper occurs in ruminants. Copper deficiency may be due to a low copper content of the forage (less than 5 ppm on the dry basis) or may be complicated with molybdenum excess or phosphorus deficiency. Reviews covering the role of copper in nutrition have been published by Marston (98) and by McElroy and Glass (101). The relation of copper to molybdenum in cattle nutrition under Florida conditions was pointed out by Becker *et al.* (12). On certain high-molybdenum muck soils the following mineral mixture has proved effective in preventing copper and cobalt deficiency caused by molybdenum: steamed bone meal 50.0 pounds, salt 46.7 pounds, pulverized copper sulfate 2.5 pounds, copper oxide 0.8 pound, cobalt carbonate 1.0 ounce. The copper requirement of cattle is not known. The addition of 1 per cent of copper sulfate to salt is usually recommended in copper-deficient areas.

According to Bentley and Phillips (19), rations with less than 10 ppm of manganese were inadequate for growth in young Holstein heifers. Twenty ppm of the ration as manganese was considered a satisfactory level for dairy cattle. This means that practical rations usually are adequate in this element.

Block and Stekol (28) reported that radioactive sulfur as sodium sulfate administered orally to a dairy cow appeared in the cystine and methionine of the milk proteins over the next 12 days. Although it has been shown with certain rations of natural feeds that adding inorganic sulfur is not beneficial (38), it may be desirable to supply additional inorganic sulfur when non-protein nitrogen is fed along with sulfur-low feeds.

Vitamins

Ruminants are especially equipped to provide many of their nutrients via the microflora of the rumen (Huffman, 70). Fatty acids, protein, and members of the vitamin B group are readily synthesized in the rumen of dairy cattle. Hence an exogenous dietary requirement for the B vitamins does not exist.

Under normal conditions natural feeds furnish the other vitamins or their precursors in adequate amounts. Vitamins A and D only assume practical importance in dairy cattle nutrition under special conditions (21). Colostrum milk contains, in addition to other essential factors, from 10 to 100 times the vitamin A potency of normal milk and hence is nature's method of providing this nutrient for the calf. Ration, age, and other factors (45, 61, 127, 142) cause nutrient variability in colostrum. Rations fed to pregnant dairy cows should therefore include feeds which contain ample carotene (vitamin A) and vitamin D.

Carotene and vitamin A. Since carotene occurs in the forages and feeds of cattle and is the precursor of physiologically active vitamin A, attention is confined herewith chiefly to the carotene requirements. The available data indicate that the carotene requirement is approximately 4 to 5 times that of vitamin A itself (31). Poorer conversion of carotene to vitamin A by the Guernsey breed (31) increases their carotene requirement, but the vitamin A requirement is similar to that of other breeds. The maintenance requirements of cattle for carotene are in the neighborhood of 1.6 mg. per 100 pounds of body weight (58, 81) Growing cattle require a minimum increase of 50 to 75 per cent carotene (83, 103) The requirement is further increased two-fold by reproduction (37). Kuhlman and Gallup (85), Blaxter (21), and Ronning *et al.* (114) suggest values of 4.5 to 9 mg. per 100 pounds of body weight for successful reproduction and lactation for extended periods (8 years). From these data it appears that 3.0–3.5, and 5.0–9.0 mg. of carotene per 100 pounds of body weight, respectively, will adequately maintain growth and reproduction in dairy cattle. If sufficient carotene is provided for growth and reproduction, there will be enough for lactation.

Including raw soybeans in the ration depresses carotene utilization (124) and thus increases the amount needed to meet the requirements of cattle. Eaton *et al.* (44) found that dairy calves did not eat sufficient amounts of field-cured alfalfa to meet the carotene requirements until after they were 5 to 6 weeks of age, whereas the higher carotene content of dehydrated alfalfa proved adequate at those ages. Dijkstra (40) reported that 2 to 7 pounds daily of grass silage or dehydrated grass furnished ample carotene to meet the requirements of cattle.

The vitamin A values of milk vary with the amount of carotene or vitamin A in the ration of the dairy cow. During the pasture season milk may contain as much as 2500 I.U. of vitamin A equivalent per quart, whereas during the winter feeding period or late fall pasture period it may fall to one-half or one-third of that value. Hauge *et al.* (65) found that feeding 300 mg. of carotene daily produced butter of a vitamin A potency approximating the maximum pasture level. When the ration contained adequate vitamin A for normal reproduction, the feeding of extra vitamin A did not result in increased milk yield (54, 78, 86, 94), but the vitamin A content of the milk was enhanced (39).

Vitamin D. Under usual feeding conditions sun-cured hay or exposure to sunlight supplies sufficient of this vitamin for dairy cattle. A study of the literature leads to the recommendation of 300 I.U. of vitamin D per 100 pounds of live weight (9). Binder-harvested corn silage which provided approximately 100 I.U. of vitamin D per 100 pounds body weight effectively cured rickets in the growing calf (11). Chopped corn silage may be deficient in vitamin D if ensiled directly from the field chopper. Data obtained by Moore *et al.* (104) show that roughages cured with limited exposure to sunlight furnish adequate vitamin D to prevent rickets in growing calves. In northern states where long barn feeding periods are common, incipient rickets in late-summer- or in fall-dropped calves occurs as evidenced by the presence of the "surcingle effect" in many calves. Hence limited feeding of vitamin D at the rate of 50 I.U. per 100 pounds may be necessary in these cases, especially during the period of rapid skeletal growth.

Wallis (135, 136) has shown that vitamin D is essential for maintenance, reproduction, and lactation of mature dairy animals. Feeding high levels of vitamin D (30,000,000 I.U.) per cow per day for 3 to 7 days prepartum and one day postpartum to cows susceptible to milk fever reduced the incidence of the disease, according to Hibbs and Pounden (67). While this treatment may have merit in the partial control of the disease, it does not follow that the disease occurs as a result of low dietary vitamin D. Such massive doses lead to soft-tissue calcification, according to Swan (128). Furthermore, continuous long-time feeding of such high levels of vitamin D is dangerous and not recommended.

Vitamin E. The dietary essentiality of vitamin E for dairy cattle was demonstrated by Gullickson and Calverley (59). Blaxter and Brown (22) present evidence which indicates that the dietary constituents of the ration affect the vitamin E requirement of cattle. The requirement of calves is less than 40 mg. of a-tocopherol per calf per day. Harris (62) in summarizing the vitamin E requirements concluded that the requirement was proportional to the body surface area, a view supported by the data of Wheeler and Perkison (139). The tocopherol content of milk increased when milk cows went to pasture (23). Wheat germ oil did not improve the breeding efficiency of bulls (121). Vitamin E deficiency is identified by its effect upon skeletal muscles in calves (27) and cardiac muscles in the cow (59). Under normal conditions natural feedstuffs supply adequate amounts of vitamin E for adult dairy cattle. However, Safford *et al.* (120) have reported muscle dystrophy in calves on western Montana ranges. The feeding of 1 to 3 ounces of cod-liver oil per calf per day caused experimental muscle dystrophy in young calves (27).

Other vitamins. Many members of the vitamin B complex are synthesized by microorganisms in the functional rumen of cattle (70, 77, 101, 134). It appears that under most conditions adequate amounts of the B vitamins are furnished to dairy cattle by a combination of natural feedstuffs and the action of the microflora of the rumen. Young dairy calves have a dietary requirement for thiamine, riboflavin, biotin, pantothenic acid, and vitamin B_{12} (41, 137, 140, 141). However, deficiencies of these vitamins in the young dairy calf cannot be demonstrated except under very restricted conditions. Hopper and Johnson (69) produced niacin deficiency in dairy calves by feeding a diet deficient in both niacin and tryptophan. Normally colostrum milk provides the B complex vitamins during the early days of life. These vitamins are also generally present in adequate amounts in natural rations to meet the requirements of young calves. Nevertheless it is possible, when whole or skim milk is replaced in the diet of the calf at an early age by dry mixtures of cereals and by-product feeds, that supplementary additions of these vitamins may be necessary.

Antibiotics

Numerous reports have been made which show that antibiotics stimulate the rate of growth of dairy calves (5, 6, 7, 29, 92, 93, 95, 106, 107, 117). The growth rate increase is greatest in the young calf. Growth depression often follows removal of the antibiotic from the ration. The effect of the antibiotic disappears at two years of age. The effect upon growth is best demonstrated with a milk-starter type ration or milk substitutes, although Loosli *et al.* (93) and MacKay *et al.* (95) have demonstrated an enhanced growth effect in young calves fed liberal quantities of milk. Growth stimulation has been obtained with 15 to 45 mg. of chlortetracycline, 50 to 90 mg., or 75 to 150 mg. per calf per day. Thirty mg. of oxytetracycline per 100 pounds of body weight appear to give a boost in growth rate equivalent to chlortetracycline. Antibiotics were found to depress cellulolytic activity and non-protein nitrogen utilization by rumen microorganisms *in vitro*. Blood plasma concentrations of vitamin B_1, riboflavin, or B_{12} were not affected by the daily ingestion of 40 to 80 mg. of chlortetracycline. Antibiotics may help in the control of scours and may improve the general health of calves in early life. Treatment of scours and other illnesses requires higher doses than are supplied in feeds. Frequently the maximum increment in growth rate with antibiotics is attained with animals fed poor type rations. Continuous feeding of antibiotics may evoke an unfavorable microorganism balance which may endanger the species so fed, according to McCoy (99) but no such instances have been reported with dairy cattle. Feeds containing antibiotics are not substitutes for good feeding and management.

Symptoms of Nutritional Deficiencies

Salt (*NaCl*)

Salt deficiency is manifested by an intense craving for salt, a lack of appetite, a generally haggard appearance, lusterless eyes, and a rough hair coat. In milking cows there is a rapid loss of weight and a decline in milk production. In high producing cows collapse may be sudden and death may rapidly ensue (3). In advanced stages of salt deficiency the cows develop neuromuscular abnormalities such as continuous shivering and a wavering walk. Recovery is rapid following the administration of salt (125). Salt deficiency in calves (123) is reflected in an unthrifty condition and a harsh coat.

Calcium

The feeding of rations low in calcium over a long period of time may bring about a depletion of calcium and phosphorus in the bones, resulting in fragile, easily fractured bones and in reduced milk yields (14). No other clinical manifestations are apparent (36).

Phosphorus

The first evidence of phosphorus deficiency is a decline in blood plasma inorganic phosphorus to subnormal levels. The normal values for cows are 4 to 6 mg. per 100 ml. and for calves under one year of age 6 to 8 mg. per 100 ml. Anorexia is the first clinical symptom of phosphorus deficiency, but it is of little diagnostic value because it is associated with other deficiencies in cattle. Depraved appetite, the chewing of substances not ordinarily classed as feed such as bones, wood, hair, etc., may be observed (47, 110). Cows, however, may suffer from extreme phosphorus deficiency without manifesting depraved appetite (73). The clinical symptoms of phosphorus and cobalt deficiencies are similar in this respect. These two deficiency diseases may be differentially diagnosed by differences in hemoglobin levels and plasma phosphorus content. Usually, if the cows in a herd are manifesting anorexia or depraved appetite or both and the calves are normal, a phosphorus deficiency is indicated (71).

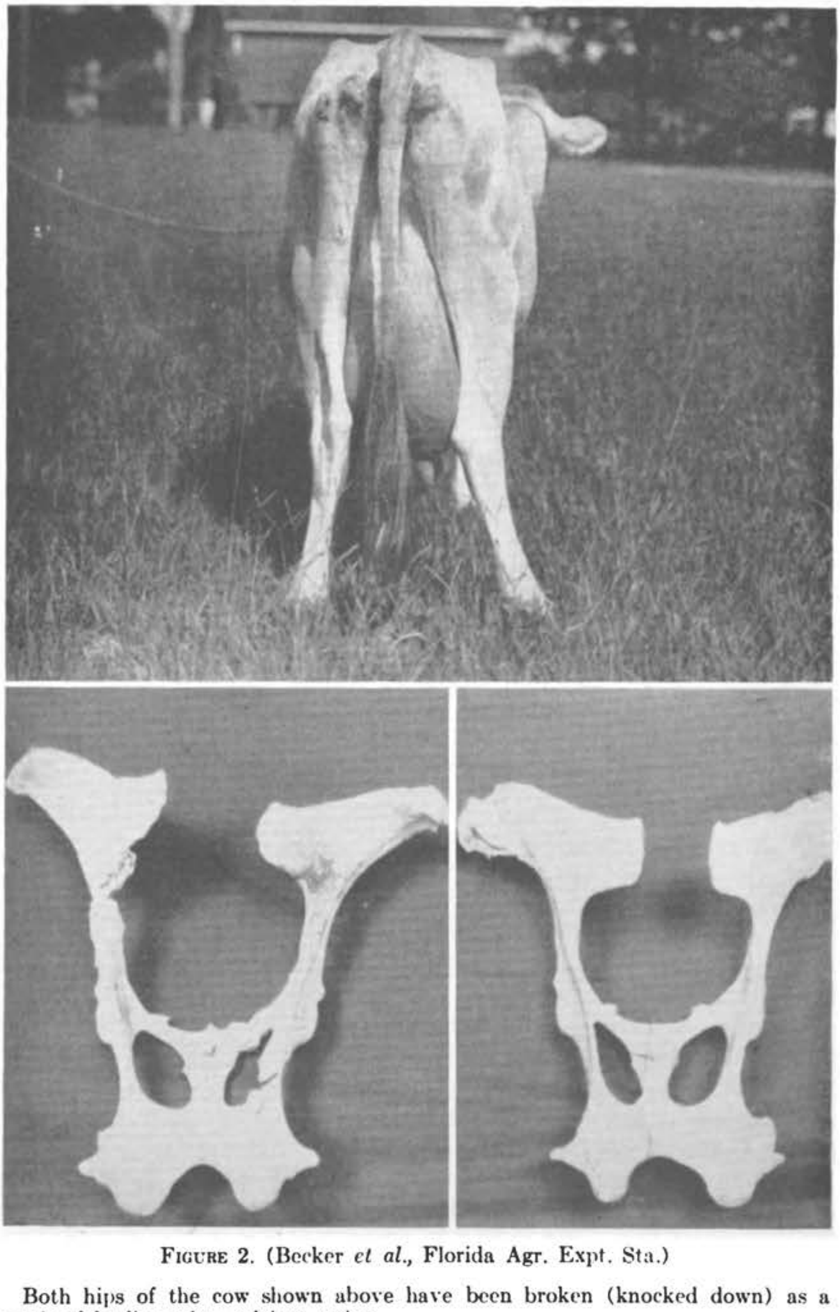

FIGURE 2. (Becker *et al.*, Florida Agr. Expt. Sta.)

Both hips of the cow shown above have been broken (knocked down) as a result of feeding a low-calcium ration.

At lower left is shown the pelvis of a cow which suffered three breaks while the cow received a low-calcium ration.

At lower right is the pelvis of the cow pictured above, showing the nature of the breaks involving both hip bones.

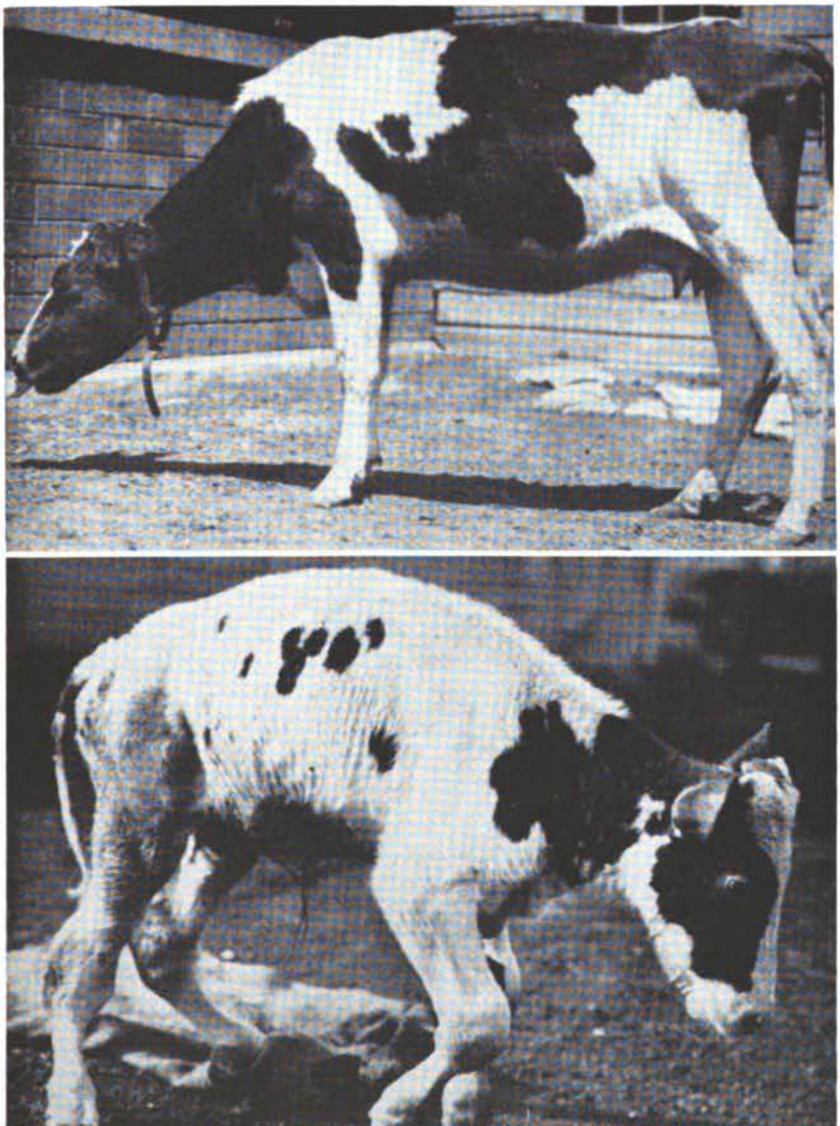

FIGURE 3

Above. A cow suffering from phosphorus deficiency and exhibiting depraved appetite. (Gullickson *et al.*, Minnesota Agr. Expt. Sta.)

Below. This calf developed severe rickets while receiving a ration deficient in vitamin D, and without sunlight. (Huffman *et al.*, Michigan Agr. Expt. Sta.)

In chronic phosphorus deficiency the animals may become stiff in the joints (14). Upon postmortem, the articulating cartilages may appear eroded. The bones of cows in phosphorus deficiency may become fragile, due to calcium and phosphorus withdrawal.

Magnesium

Deficiency of magnesium *per se* has not been observed in cattle under farm conditions. A disease known as "grass" or "lactation" tetany occurs which is manifested by low plasma magnesium values although the magnesium intake is in the normal range (4). Among the early symptoms in calves of experimentally produced magnesium deficiency are irritability and anorexia. The animal, temporarily blinded, runs into obstacles or may turn in circles until its balance is completely lost. As the convulsion (tetany) becomes more violent, the calf may fall on its side with the legs alternately rigidly extended and contracted. There is frothing at the mouth and profuse salivation. These attacks may last continuously for several minutes or intermittently for a long time. Young calves seem to be able to withstand several convulsions, but older calves usually succumb to the first attack (43). Blaxter *et al.* (25) observed opisthotonus and ataxic gait.

Iodine

A deficiency of iodine is manifested by the production of dead or non-viable goitrous calves as a result of a lack of iodine in the ration of the dam. There is a swelling of the thyroid gland of the calf, which is frequently referred to as "big neck." The trouble can be prevented by feeding iodized salt to the cow during the gestation period.

Iron

The only symptom of iron deficiency in calves is anemia or low hemoglobin (131). The iron deficiency studies with older animals, reported in the literature, have been complicated by the possibility of accompanying cobalt or copper deficiencies. The iron requirement is probably very low and in most instances can be met by the iron present in practical rations.

Cobalt

When the ration contains insufficient cobalt, animals may show a gradual loss of appetite, progressive emaciation, rough coat, listlessness, and eventually anemia. Depraved appetite is often observed. There is a marked decrease in milk production and body weight in cows (1). However, these symptoms, other than anemia in the final stages, are similar to phosphorus deficiency. Other than blood plasma inorganic phosphorus determinations, the best practical method of differentiating these two deficiencies is as follows: If the calves under one year of age are healthy and the cows have poor appetites, feed a phosphorus supplement. If the calves are unthrifty and have poor appetites, but the cows have good appetites, feed a cobalt supplement. If appetite does not recover within a week, add a phosphorus supplement (71).

Copper

According to Becker *et al.* (12) most cases of copper deficiency start with a severe diarrhea, followed by a rapid loss in weight, cessation of growth, abnormal

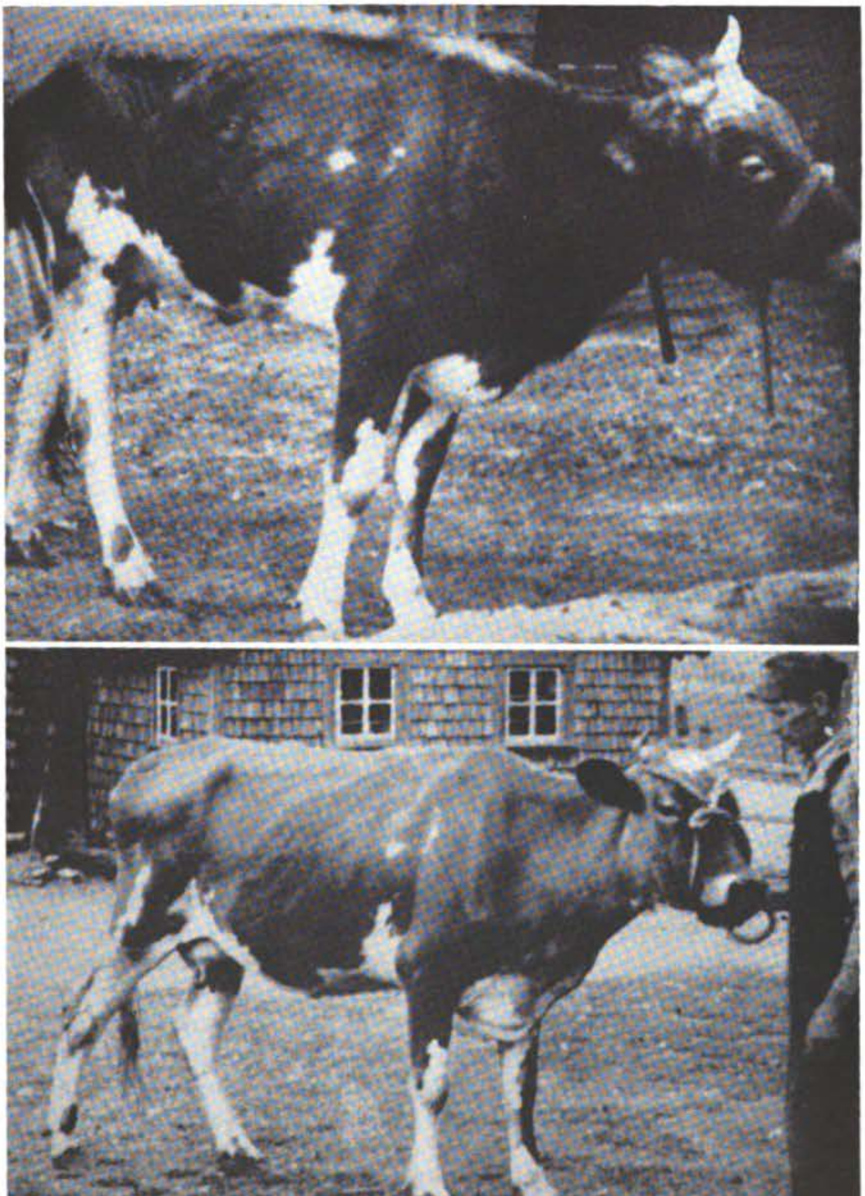

FIGURE 4. (Huffman *et al.*, Michigan Agr. Expt. Sta.)

A milking cow suffering from cobalt deficiency (above) and the same cow 16 days after starting cobalt feeding (below).

appetite, rough, coarse, bleached hair coat, and anemia. A readily noticed characteristic of copper deficiency is a swelling of the ends of the leg bones, especially above the pasterns. The bones become very fragile, often resulting in multiple fractures of ribs, femur, or humerus. Osteomalacia develops in mature cattle. Cows in a copper-depleted condition may fail to conceive or have difficulty at calving (retained placenta) or give birth to calves with congenital rickets. Affected animals may develop a pacing gait. "Falling disease" in cattle is due to a copper deficiency (17, 18).

The presence in forages of excess molybdenum results in diarrhea and bleaching of the hair coat, which can be cured or prevented by increasing the copper intake (12, 33, 50).

Vitamin A

A vitamin A deficiency is easily detected by blood plasma vitamin A analysis (31). The normal concentrations for the young calf are 10 µg. or more of vitamin A per 100 ml. of plasma. Concentrations of 7 to 8 µg. of vitamin A per 100 ml. will cause the calf to exhibit mild deficiency symptoms, while those of 5 µg. of vitamin A or less will produce all the symptoms associated with the advanced stages of the disease. The blood plasma concentration of vitamin A in adult cattle during the long winter feeding period in the northern states declines from a pasture level of 60 or more to about 15 µg. per 100 ml. In the young calf, symptoms of the deficiency (mild to begin with but severe if they continue) usually start with "watery eyes," cold in the head with a nasal discharge, sometimes a cough, and scours or diarrhea. Calves exhibit these symptoms for several days to several weeks and usually succumb to pneumonia.

The first easily detected gross symptom of vitamin A deficiency is night blindness, readily observed when animals are driven about in a dim light (57). Muscular incoordination, staggering gait, and convulsive seizures may develop as a result of elevation of the cerebro-spinal fluid pressure. Blindness in young growing cattle also occurs without the classical signs of the vitamin A deficiency syndrome as the result of stenosis of the optic foramen and chronic optic neuritis (102). In these cases blindness develops without keratitis. A lack of vitamin A causes the transformation of normal epithelial structures to stratified keratinized epithelium (epithelial metaplasia). The mucosa of the respiratory tract, buccal cavity, salivary glands, eyes, lacrimal glands, intestinal tract, urethra, kidney, and vagina are thus changed in the vitamin A-deficient bovine. Structures thus affected are very susceptible to infection, and as a result colds and pneumonia often occur. Frequent convulsions are manifested in the advanced stages of the deficiency. Diarrhea, loss of appetite, and emaciation are common features of the disease at this stage.

Subclinical vitamin A deficiency may be associated with the development of a roughened hair coat, general unthriftiness, emaciation, and dry pityriasis (bran-like scales of the skin) particularly about the neck and withers and along the back extending to the tail-head. In the later stages, characteristic changes in the eye may take place: early excessive and exhaustive lacrimation, keratitis (corneal inflammation), a softening of the cornea, xerophthalmia (dry form of conjunctivitis), opacity and cloudiness of the cornea, and total blindness from infection. In the pregnant animal, vitamin A deficiency results in abortion or birth at term of dead, weak, or blind calves.

Vitamin D

Avitaminosis D is a disease affecting the growing bovine. One of the first symptoms of low vitamin D rickets is a decrease in the blood plasma concentration of calcium or inorganic phosphorus or both. These blood changes cause characteristic alterations in the bones, indicating a markedly retarded calcification of the cartilaginous matrix (116).

Clinical symptoms begin with thickening and swelling in regions of the metacarpal (pastern or ankle) or metatarsal bone or both. With the progress of the disease, the forelegs bend forward or sideways or both. The joints, particularly the knee and hock, become swollen and stiff, the pastern straight, and the back humped. In the more severe cases synovial fluid accumulates in the joints. Posterior paralysis may occur as the result of fractured vertebrae. The advanced stages of the disease are marked by stiffness of gait, dragging of the hind feet, irritability, tetany, labored and fast breathing, anorexia except for milk, weakness, and retardation of growth (8, 9). On autopsy the gall bladder is frequently distended by accumulation of a viscous ropy orange-yellow bile. Enteritis occasionally occurs.

Thiamine

On a thiamine-deficient diet dairy calves become weak and develop incoordination of the legs, retraction of the head, convulsions, and in some cases severe scouring, anorexia, and dehydration. Thiamine injections alleviate the symptoms of polyneuritis (81).

Riboflavin

Young calves require a dietary source of riboflavin (137, 140). When the diet is deficient in riboflavin the calf develops hyperemia of the buccal mucosa and lesions in the corner of the mouth, along the edges of the lips, and around the nose. There is loss of appetite, and growth is poor or ceases entirely. Severe scours develop, and excessive salivation and lacrimation are characteristic. A loss of hair occurs on various parts of the body but is most marked around the navel. Preliminary observations fail to reveal vascularization of the cornea or opacity of the lens in any of the animals.

Biotin

Studies by Wiese *et al.* (141) have shown that the young calf requires a dietary source of biotin. On a biotin-deficient diet, calves develop paralysis of the hind quarters which is curable by the administration of biotin. Pathological changes associated with a deficiency of biotin have not been reported.

Pantothenic Acid

Johnson *et al.* (80) have reported that the young dairy calf requires pantothenic acid. On a pantothenic acid-free ration calves exhibited diarrhea, cessation of growth, and weakness of the legs with inability to stand.

Vitamin B_{12}

Draper *et al.* (41), by means of a synthetic milk, produced a vitamin B_{12} deficiency in the dairy calf, manifested by no growth, poor appetite, and incoordination. Some demyelination occurred in the peripheral nerves. These symptoms were accompanied by biliary obstruction. Lassiter *et al.* (88) likewise produced a vitamin B_{12} deficiency in calves fed a synthetic milk low in B_{12}, and noted cessation of growth, poor condition, anorexia, and weakness. On postmortem the liver had white spots on its surface. These workers obtained evidence that the requirement was greater than 10 μg. but below 40 μg. per kg. of dry matter intake.

Nicotinic Acid

Hopper and Johnson (69) reported the deficiency symptoms of nicotinic acid, or niacin, to be loss of appetite, severe scouring, dehydration, and weakness followed by death on the second or third day on a deficient diet.

Composition of Feeds

The composition of the feeds most commonly used for dairy cattle is shown in table 3. The average composition of the common calcium and phosphorus supplements available on the market is summarized in table 4.

Average carotene values of roughages are less reliable than those for other nutrients because of sample variation and also because carotene is unstable. It decreases rapidly during storage at high temperatures but is relatively more stable in most feeds at low temperatures. The best practical guide to the vitamin A activity of roughages, aside from carotene analyses, is the degree of green color present in the hay. The data in table 5 may be used as a general guide in estimating the carotene content of feedstuffs.

Examples of Adequate Rations

The sample rations in table 6 have been calculated from the requirements in table 1 and the average composition of feedstuffs in tables 3 and 4 to illustrate how the data presented can be used to formulate adequate rations for dairy cattle during growth and lactation. The sample rations show that combinations of a limited number of feedstuffs, when properly chosen, will provide for adequate nutrition of dairy cattle. Experimental evidence has shown that it is unnecessary to provide protein or any other nutrient from several sources. Commercially manufactured concentrate mixtures generally contain six to ten different ingredients, but this is merely a manufacturing expediency and the larger number of components does not necessarily improve the ration. The quality of a mixed feed depends largely upon its composition rather than merely upon the number of ingredients it contains.

As a rule, for convenience, concentrate mixtures for dairy cattle are premixed before feeding rather than the different feeds being fed separately as is often done in group feeding of beef cattle or sheep. The protein content of the concentrate mixture should be varied according to the protein content of the roughage. Suggested concentrate mixtures of differing protein content are presented in table 7 to illustrate the varying needs of dairy cattle fed several types of roughages.

In general, the more common feedstuffs can be grouped into four classes with respect to protein content, as follows: (1) *Low protein:* corn, corn and cob meal, hominy feed, barley, oats, wheat, rye, beet or citrus pulp, and molasses. (2) *Medium protein:* wheat bran, wheat middlings, and wheat mixed feed. (3) *High protein:* corn gluten feed, distillers' dried grains, brewers' dried grains, and coconut oil meal. (4) *Very high protein:* cottonseed oil meal, soybean oil meal, soy-

TABLE 3

AVERAGE COMPOSITION AND DIGESTIBLE NUTRIENTS

Feedstuff	Total dry matter	Protein	Dig. protein	TDN[1]	DE[2]	Calcium	Phosphorus	Carotene
	%	%	%	%	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	Phosphorus	Carotene
	%	%	%	%	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	Phosphorus	Carotene
	%	%	%	%	*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. Exp. 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, steamed	30.0	136	13.9	63	0.037
Defluorinated rock phosphate[1]	29.0	132	13.0	59	0.15 or less
Dicalcium phosphate	26.5	120	20.5	93	0.05
Limestone (high calcium)	38.3	174	nil	nil	—
Oyster shell flour	36.9	167	nil	nil	—

[1] High quality defluorinated rock phosphate should contain this amount of calcium and phosphorus and be no higher in fluorine than shown. For long time feeding to dairy animals, high quality products should be used.

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.

TABLE 6

EXAMPLES OF ADEQUATE RATIONS
For Normal Growth and Lactation

	Total feed	Digestible protein	TDN	DE[1]	Calcium	Phosphorus	Carotene
	lb	*lb*	*lb*	*therms/lb*	*gm*	*gm*	*mg*
100-pound calf							
Nutrient requirements	—	0.40	2.0	4.0	7	6	4
Ration in pounds:							
Whole milk, 12.0	—	0.40	1.94	3.9	6.5	3.4	—
400-pound heifer							
Nutrient requirements	11	0.80	6.5	13.1	13	12	16
Ration in pounds:							
A. Mixed clover-timothy hay 8.0, yellow corn 1.0, oats 1.0, linseed meal 1.0	11	0.85	6.4	12.9	29	16	72
B. Legume hay 10.0, yellow corn 2.0 (oats or barley)	12	1.73	6.6	13.3	67	13	117
600-pound heifer							
Nutrient requirements	15	0.85	8.5	17.2	13	12	24
Ration in pounds:							
A. Mixed legume-grass hay 10.0, oats 5.0 (corn or barley)	15	0.90	8.5	17.2	30	12–15	90
B. Alfalfa hay 15.0	15	1.58	7.6	15.4	100	16	170
C. Timothy hay 10.0, barley 5.0, limestone 0.05	15	.79	8.8	17.8	20	20	.53
D. Alfalfa hay 10.0, corn silage 15.0	25	1.23	7.8	15.8	73.5	15	210
Mature lactating cows:							
1400-pound cow giving 50 lb. 4% milk							
Nutrient requirements	—	3.05	26.5	53.5	61	46	56
Ration in pounds:							
A. Alfalfa 35, barley 12	—	4.87	26.9	54.3	279	94	400
B. Timothy hay 14, corn silage 42, corn and cob meal 12, soybean meal 5, limestone 0.2	—	3.36	27.0	54.5	65	59	340
C. Alfalfa hay 20.0, corn silage 50.0	—	3.30	26.8	54.1	156.8	46.2	558
1000-pound cow giving 35 lb. 5% milk							
Nutrient requirements	—	2.35	21.0	42.4	43	32	40
Ration in pounds:							
A. Alfalfa hay 5, citrus pulp 12, hominy feed 10, cottonseed meal 2	—	2.45	21.3	43.0	161	46	57
B. Clover-timothy mixed hay 10, corn silage 30, barley 4, oats 5, wheat bran 5	—	2.37	20.4	41.2	51	49	242
C. Alfalfa brome hay 25.0 (at least 50% alfalfa), corn 11.0	—	2.69	21.2	42.8	95.9	43	—
D. Alfalfa 15.0, corn silage 30.0, corn 10.0	—	2.48	21.0	42.4	100.8	42.2	421
E. Clover-timothy 25.0 (30 to 50% clover), corn 10.0, soybean oil meal 1.0	—	2.24	21.5	43.4	79.6	37.6	—

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

TABLE 7

SUGGESTED CONCENTRATE MIXTURES FOR DAIRY ANIMALS

Roughage	Total protein in grain mixture	Ingredients[1]			
		Corn	Oats	Wheat bran	Soybean oil meal
	%	*lb*	*lb*	*lb*	*lb*
Legume hay or legume silage (alfalfa, clover, soybean, etc.)	12–14	400	300	300	—
Legume hay and corn or grass silage or mixed hay and silage	14–16	300	300	300	100
Mixed hay and silage	16	200	300	300	200
Grass hay and corn silage[2]	16–18	100	300	300	300

[1] It is recommended that 1% salt be added. In phosphorus-deficient areas, 1% of bonemeal or other fluorine-low phosphorus supplement should be added.
[2] Add 1% calcium carbonate or ground limestone.

beans, peanut oil meal, and linseed oil meal. For the most part the feeds within a class can be used interchangeably in planning concentrate mixtures.

The requirement values and the example rations serve only as approximate guides to proper feeding of dairy cattle. Feed combinations can be calculated which meet the specifications set forth in the various tables but which might be unsatisfactory for long-time use. In the final analysis the amounts and, to some extent, the types of feeds should be governed by the condition of the animals, their ability to handle the feed, and the type or rate of growth or production desired.

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