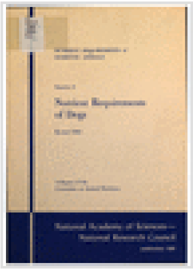

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NUTRIENT REQUIREMENTS of
DOMESTIC ANIMALS

Number 8

# Nutrient Requirements of Dogs

Revised 1962

*A Report of the*
COMMITTEE ON ANIMAL NUTRITION

*Prepared by the*
SUBCOMMITTEE ON CANINE NUTRITION

Agricultural Board
Division of Biology and Agriculture

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# FOREWORD

*Nutrient Requirements of Dogs* is the eighth of a series of reports issued by the Committee on Animal Nutrition of the Agricultural Board, National Academy of Sciences—National Research Council. Reports on nutrient requirements of poultry, swine, dairy cattle, beef cattle, sheep, horses, and mink and foxes have been published previously. A report on nutrient requirements of laboratory animals published in 1962 completed the series.

The information on requirements of dogs was prepared by a special Subcommittee on Canine Nutrition of the Committee on Animal Nutrition. This subcommittee is composed of animal nutritionists who have used dogs extensively in nutrition research. This revised report of the subcommittee thus presents nutrient requirements of the highest degree of reliability in the light of the available evidence.

Knowledge of the nutrient requirements of dogs is by no means complete, in spite of the fact that it is now possible to compose good dog rations which appear to be adequate for growth, maintenance, and reproduction. The work of the Subcommittee on Canine Nutrition is therefore not ended with the preparation of this report. Whenever sufficient new experimental evidence is obtained on the nutrient requirements of dogs, the report will be revised and enlarged to bring them up to date.

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# NUTRIENT REQUIREMENTS OF DOGS

The role of dogs as pets and companions, as well as aids in hunting and in some occupations, makes their feeding a matter of personal concern to many owners. The desires of dog owners to satisfy the appetites of their pets for certain types of foods often influence feeding practices. Although dogs are by nature carnivorous, vegetable and cereal products are acceptable foodstuffs when used in proper combinations.

Estimations of the nutritional requirements of dogs are complicated by the great variation in size, body conformations, hair coat, activity, and disposition which must be considered. These range all the way from the thinly clad Chihuahua to the heavy-coated, hard-working Husky. Rather than attempting to cover all extremes of size and condition, the Subcommittee on Canine Nutrition has estimated the nutritional requirements of moderate-sized (15–30 lb) normally active dogs. These values, listed in Tables, 1, 2, and 3, can be adjusted to cover specific conditions. They should provide adequately for maintenance of normal dogs. Smaller or more active dogs require more energy per pound of body weight. Dogs of the same size and breed often require different amounts of food, even when maintained under apparently identical conditions.

Feeding thus becomes an individual matter, and the requirements serve only as guides. These requirements have been determined by the Subcommittee on Canine Nutrition after thorough consideration of the data reported in scientific literature or from unpublished data. The data reflect the present-day evidence of nutrient requirements. There is sufficient evidence to show that the amounts listed are adequate, but in some cases there are no data to show whether these amounts are as low as they might safely be. Insofar as can be determined, the use of nutrients at the ratios listed will prevent harmful excesses as well as deficiencies. Additional information is needed if values closer to the minima are to be established.

# DISCUSSION OF REQUIREMENTS

## *Energy-Calories*

Since efficient utilization of many nutrients proceeds only when the entire diet provides adequate food energy, the requirements for all nutrients are based upon the assumption that adequate calories are to be supplied in the diet. If this is not the case, the energy deficit may cause utilization of protein and fat for energy rather than for other essential requirements.

Individual dogs vary greatly in their energy requirements, even when

## TABLE 1

NUTRIENT REQUIREMENTS OF DOGS[1]
(In percentage or amount per pound of food)

| Nutrient | On a dry basis | Dry-type dog food | Canned or wet mixtures |
|---|---|---|---|
| | % | % | % |
| Dry Matter | 100 | 91 | 28 |
| Protein | 22.0 | 20.0 | 6.7 |
| Carbohydrate (Maximum) | 71.5 | 65.0 | 20.0 |
| Fat | 5.5 | 5.0 | 1.5 |
| Calcium | 1.1 | 1.0 | 0.3 |
| Phosphorus | 0.9 | 0.8 | 0.24 |
| Potassium | 0.9 | 0.8 | 0.24 |
| Sodium chloride | 1.5 | 1.4 | 0.43 |
| Magnesium | 0.5 | 0.4 | 0.14 |
| | Mg per lb of feed | Mg per lb of feed | Mg per lb of feed |
| Iron | 26 | 24 | 7 |
| Copper | 3.3 | 3 | 1 |
| Cobalt | 1.1 | 1 | 0.3 |
| Manganese | 2.2 | 2 | 0.6 |
| Zinc | 2.2 | 2 | 0.6 |
| Iodine | 0.7 | 0.6 | 0.20 |
| Vitamin A | 0.7[2] | 0.6[2] | 0.18[2] |
| Vitamin D | 0.0033[3] | 0.0033[3] | 0.001[3] |
| Vitamin E (growth) | 22.0[4] | 20.0[4] | 6.0[4] |
| Vitamin $B_{12}$ | 0.01 | 0.01 | 0.003 |
| Folic acid | 0.08 | 0.07 | 0.02 |
| Thiamine | 0.33 | 0.3 | 0.10 |
| Riboflavin | 0.98 | 0.8 | 0.24 |
| Pyridoxine | 0.44 | 0.4 | 0.12 |
| Pantothenic acid | 0.99 | 0.9 | 0.3 |
| Niacin | 4.8 | 4.4 | 1.3 |
| Choline | 550. | 500. | 150. |

[1] The values shown are based upon dry and canned foods containing 91 and 28 per cent dry matter. Moisture has been included to indicate general level of composition rather than as a requirement. There is no evidence that carbohydrate as such is required, but since it occurs as a part of many dog-food ingredients, a maximum value has been suggested.

[2] The 0.6 and 0.18 mg quantity of crystalline vitamin A is equal to 2000 and 600 IU, respectively. One mg vitamin A alcohol = 3,333 IU of vitamin A. One mg beta carotene = 1,667 IU of vitamin-A activity. For dogs carotene is approximately one-half as valuable as vitamin-A alcohol.

[3] These amounts of pure vitamin D correspond to 120 and 40 IU per pound of feed.

[4] As alpha tocopherol.

## TABLE 2

NUTRIENT REQUIREMENTS OF DOGS[1]
(Amounts per pound of body weight per day)

| | Weight of dog in pounds | Adult maintenance | Growing puppies |
|---|---|---|---|
| Energy (kcal)[2] | 5 | 50 | 100 |
| | 10 | 42 | 84 |
| | 15 | 35 | 70 |
| | 30 | 32 | 64 |
| | 50 and over | 31 | 62 |
| Protein–minimum (gm) | | 2.0 | 4.0 |
| Carbohydrate–maximum (gm)[3] | | 4.6 | 7.2 |
| Fat (gm) | | 0.6 | 1.2 |
| Minerals: | | | |
| Calcium (mg) | | 120 | 240 |
| Phosphorus (mg) | | 100 | 200 |
| Iron (mg) | | 0.600 | 0.600 |
| Copper (mg) | | 0.075 | 0.075 |
| Cobalt (mg) | | 0.025 | 0.025 |
| Sodium Chloride (mg) | | 170 | 240 |
| Potassium (mg) | | 100 | 200 |
| Magnesium (mg) | | 5 | 10 |
| Manganese (mg) | | 0.050 | 0.100 |
| Zinc (mg) | | 0.050 | 0.100 |
| Iodine (mg) | | 0.015 | 0.030 |
| Vitamins: | | | |
| Vitamin A (IU)[3] | | 45 | 90 |
| Vitamin D (IU)[3] | | 3 | 9 |
| Vitamin E (mg) | | – | 1 |
| Vitamin $B_{12}$ (mg) | | 0.0003 | 0.0006 |
| Folic acid (mg) | | 0.002 | 0.004 |
| Riboflavin (mg) | | 0.020 | 0.040 |
| Pyridoxine (mg) | | 0.010 | 0.020 |
| Pantothenic acid (mg) | | 0.023 | 0.045 |
| Niacin (mg) | | 0.110 | 0.180 |
| Choline (mg) | | 15 | 30 |

[1] Symbols—gm = gram; mg = milligram; IU = International Unit.
[2] Values listed are for gross or calculated energy. Biologically available energy is ordinarily 75–85 per cent of the calculated.
[3] See Footnotes 1, 2, and 3, Table 1.

they are of the same size and activity level and when they are in comparable environments. This individual variation, plus the large range in size of dogs, the conditions of activity, and the temperature of their environment, makes generalization regarding specific energy requirements hazardous.

Since the energy requirement per pound of body weight tends to vary in-

# TABLE 3

## Estimated Daily Food Intakes Required by Dogs of Various Sizes

| Weight of dog | Requirements for maintenance: Dry type foods[1] | | Requirements for maintenance: Canned dog food[2] | | Requirements for growth: Dry type foods[1] | | Requirements for growth: Canned dog food[2] | |
|---|---|---|---|---|---|---|---|---|
| | Per lb body wt | Per dog | Per lb body wt | Per dog | Per lb body wt | Per dog | Per lb body wt | Per dog |
| lbs | lbs | lbs | lbs | lbs | lbs | lbs | lbs | lbs |
| 5 | 0.040 | 0.20 | 0.120 | 0.60 | 0.080 | 0.40 | 0.240 | 1.20 |
| 10 | 0.033 | 0.33 | 0.101 | 1.01 | 0.066 | 0.66 | 0.202 | 2.02 |
| 15 | 0.028 | 0.42 | 0.085 | 1.27 | 0.056 | 0.84 | 0.190 | 2.54 |
| 20 | 0.027 | 0.54 | 0.081 | 1.60 | 0.054 | 1.08 | 0.160 | 3.20 |
| 30 | 0.025 | 0.75 | 0.077 | 2.30 | 0.050 | 1.50 | 0.154 | 4.60 |
| 50 | 0.025 | 1.25 | 0.075 | 3.74 | 0.050 | 2.60 | 0.150 | 7.48 |
| 70 | 0.025 | 1.75 | 0.075 | 5.23 | 0.050 | 3.50 | 0.150 | 10.46 |
| 110 | 0.024 | 2.64 | 0.074 | 8.22 | 0.048 | 5.28 | — | — |

[1] Dry foods contain 6–12 per cent moisture. Calculations of the amounts of dry food required have been based on energy supplied by food containing 91 per cent dry matter, 76 per cent protein plus carbohydrate, 5 per cent fat and 10 per cent ash, fiber and other inert material. This supplies a calculated 1583 kcal per pound, of which it is estimated that 80 per cent or 1266 kcal are digestible.

[2] Calculated on the basis of 28 per cent dry matter and the same nutrient ratios as in 1, with the total and available energy calculated as 490 and 415 (85 per cent of the total) kcal per pound.

## TABLE 4

ENERGY AND FOOD REQUIREMENTS FOR DOGS[1]

| Body wt | | ENERGY per kg body wt | ENERGY per lb body wt | Daily ration[2] 91% dry matter | Daily ration[2] 30% dry matter |
|---|---|---|---|---|---|
| kg | lbs | kcal | kcal | gms | gms |
| 1 | 2.2 | 141 | 64 | 35 | 118 |
| 2 | 4.4 | 117 | 53 | 58 | 195 |
| 3 | 6.6 | 105 | 48 | 79 | 262 |
| 4 | 8.8 | 97 | 44 | 97 | 323 |
| 5 | 11.0 | 91 | 41 | 114 | 380 |
| 6 | 13.2 | 87 | 39 | 130 | 433 |
| 7 | 15.4 | 84 | 38 | 146 | 487 |
| 8 | 17.6 | 81 | 37 | 161 | 537 |
| 9 | 19.8 | 78 | 35 | 175 | 583 |
| 10 | 22.0 | 75 | 34 | 189 | 630 |
| 20 | 44.0 | 62 | 28 | 313 | 1,040 |
| 30 | 66.0 | 56 | 25 | 423 | 1,410 |
| 40 | 88.0 | 52 | 24 | 523 | 1,740 |
| 50 | 110.0 | 49 | 22 | 613 | 2,043 |

[1] Adapted from Table 1, Arnold and Elvehjem (11).
[2] The dry and moist rations contained 1,800 and 550 kcal per pound, respectively.

versely with total body weight, any reasonably accurate estimate of caloric needs must take body weight into account. Arnold and Elvehjem (11) estimated the energy required to maintain adult dogs from the maintenance prediction values of Brody, Proctor, and Ashworth (23), and obtained experimental evidence to show the values listed in Table 4 to be substantially correct. These values are also in agreement with the calorie requirements indicated by a formula devised by Cowgill (33).

In an extensive study of energy in relation to food intake, Cowgill (33) demonstrated that dogs given all the diet they would consume during one three-hour period a day voluntarily adjusted their food intake over a period of time to a level which would maintain a constant body weight. For dogs maintained in laboratory cages, energy intake varied from 45 kcal per pound of body weight per day for a 7.5-lb dog to 30 kcal per pound of body weight for a 33.0-lb dog. For an intermediate size, 17.5 lbs, the value was 35 kcal per pound of weight per day. The diets used were highly digestible, being composed of casein or meat protein, sucrose, fats, vitamins, and minerals. These values are probably generous as they allow voluntary adjustment of weight levels, but they are in general agreement with findings reported in several well-controlled experimental studies and by kennels using commercial dog foods.

Thus, Reber and his associates (119, 120) noted that Beagles fed a diet based upon white flour (35 per cent), horse meat (25 per cent as solids), tallow (10 per cent), soybean meal (12 per cent), and minor ingredients to assure adequacy of protein, vitamin, and mineral supplies, voluntarily consumed enough food to gain well as young dogs and to maintain weight as adults. Their diet supplied approximately 37 per cent moisture, 28 per cent carbohydrate, 16 per cent protein, 14 per cent fat, and five per cent ash, and a calculated 1,365 kcal per pound of diet. Young dogs (14 to 18 weeks of age) weighing 8.4 to 15.8 lbs voluntarily consumed 51–61 calories per day per pound of body weight during a five-week period. During the 33rd to 38th week of the experiment, the gross energy intake had decreased to 36–42 kcal per pound per day, even though the dogs were still gaining slowly.

In another well-controlled experiment, Hale (62) showed that dogs became excessively fat when offered generous feedings of a palatable diet. Young adult Beagles weighing 18–26 lbs could maintain weight or gain slightly on intakes limited to 800 kcal (36/lb) from a readily digestible high-protein, high-fat diet. If the diet was allowed ad libitum, the dogs became excessively fat. The energy intakes ranged from 31.1 kcal per pound of body weight (nine per cent loss) to 47.5 kcal per pound (14 per cent gain) in 12 weeks. The average intake was 39 kcal per pound per day and the average gain was one pound per animal (about five per cent) over a 12-week period. In a similar series of tests, the same laboratory found that diets higher in fiber (20 per cent of the solids as cabbage) required more gross energy for weight maintenance. In this case, the gross energy content of the diet consumed ranged from 40 to 76 kcal per pound body weight for dogs averaging 18.5 lbs. The average energy intake was 69 kcal per pound, with a weight gain of five per cent in 12 weeks. Hale states that the cabbage was not well digested and that a few of the animals showed abnormal skin conditions.

James and McCay (73) also showed that several types of large dogs would consume more food than needed to maintain weight when fed a commercial-type meal diet. Dogs restricted to one pound of food for 36 lbs of body weight remained in good condition. Calculations from the ingredients given for the diet used indicate that this one pound supplied about 1,550 kcal, corresponding to 43 kcal per pound of body weight. If this is decreased by about 20 per cent to allow for incomplete digestibility, the value agrees well with those shown in Table 3. These same workers showed that food requirements are correlated with activity but not with age. Similar energy requirements were shown by several breeds of dogs fed canned dog foods for periods of at least three months (121). Detailed data for several dogs, as shown in Table 5, indicate the variability which may be expected from animal to animal and show energy consumptions of dogs which were essentially in weight equilibrium and maintained in excellent condition. These calorie values, when corrected for digestibility, are in the general range of the predicted energy requirements of Table 4.

Growing puppies require much more food than adult dogs, the amount again depending upon the individual puppy and its rate of growth. Arnold and Elvehjem (11) showed that growing Airedale puppies required twice as much food as adult dogs. Puppies fed 1.5 times the estimated maintenance level for adult dogs, failed to gain satisfactorily, and at 2.5 times the

## TABLE 5[1]

KCAL REQUIRED FOR MAINTENANCE OF DOGS FED CANNED DOG FOODS[2]

| Breed | Sex | Body wt | ENERGY per day | ENERGY per lb body wt |
|---|---|---|---|---|
| | | lbs | kcal | kcal |
| Beagle | Female | 12.2 | 593 | 49 |
| Beagle | Female | 22.5 | 932 | 42 |
| Beagle | Male | 24.5 | 1,028 | 42 |
| Beagle | Male | 23.8 | 1,028 | 43 |
| Beagle | Male | 30.3 | 1,198 | 40 |
| Beagle | Female | 30.0 | 1,040 | 35 |
| Wirehair | Female | 18.5 | 1,020 | 55 |
| Wirehair | Male | 22.0 | 1,010 | 46 |
| Wirehair | Male | 16.6 | 836 | 50 |
| Cocker | Female | 26.4 | 948 | 36 |
| Cocker | Female | 25.0 | 765 | 30 |
| Cocker | Female | 20.9 | 984 | 47 |

[1] Reference (121).
[2] The food contained approximately 80 per cent digestible energy.

estimated adult food levels, puppies became fat. Hence, a doubling of the estimated maintenance level for adults should be approximately correct for puppies. This must be gradually reduced to the adult requirement as the puppies mature. Puppies, like adult dogs, may become excessively fat if allowed voluntarily to consume palatable rations. Food intakes should be adjusted to permit steady growth without excessive fatness.

During gestation, bitches require more food than during maintenance periods. Unpublished data reported by Reber show that bitches fed the diet previously described require 38–43 kcal per day per pound of body weight during gestation (120). These are weekly averages for 22 Beagles, and Reber observed that the caloric intake gave a constant figure when calculated on the basis of body weight. The increase in body weight as gestation proceeds adequately reflected the increased need for energy. Since these are the same animals for which Reber reported 36–42 kcal per pound per day as adequate for maintenance as young adults, it may be seen that the gestation requirements do not greatly exceed the maintenance requirement when calculated on a body-weight basis.

The energy needed for lactation is obviously much higher than that for maintenance or gestation. In the previously cited work with Beagles, Reber found the average kcal per day per pound of body weight to increase from the gestation level of 38–43 kcal to 48 during the first week of lactation, and from there gradually to 125 kcal per day per pound of body weight during the 8 weeks of lactation. These are average figures for 16 bitches and must be considered only as an illustration of intakes during lactation since individuals varied from 18 to 78 kcal per day per pound body weight during the first week, and from 65 to 200 during the eighth week. For the entire eight-week period, the average daily intakes varied from 56 to 145 kcal per pound initial body weight, and weight changes varied from a 27 per cent loss to a 15 per cent gain. Gain or loss could not be correlated with the number of pups and must be considered as an indication of the great variation encountered even in dogs of a single breed.

## *Protein*

Dietary proteins are hydrolyzed in the gastrointestinal tract to supply amino acids for synthesis of tissue proteins and to meet other metabolic needs. Twenty-two different amino acids are required daily for this purpose. Some of these amino acids can be synthesized by the dog if the diet contains sufficient protein, but nine of the amino acids cannot be synthesized in adequate amounts. These acids are "essential" or "indispensable" and must be provided by the diet (122). The indispensable amino acids are histidine, leucine, isoleucine, lysine, phenylalanine, methionine, threonine, tryptophan, and valine. Those that can be synthesized from amino acids provided by the diet are called "non-essential" or "dispensable."

The nutritive value of dietary protein is largely determined by the amounts and proportions of indispensable amino acids supplied to the body. The indispensable amino acids potentially available in some common dietary protein sources are listed in Table 6. Arginine is included in this table because this amino acid may be "essential" under conditions of growth or repletion. Since part of the phenylalanine may be needed for synthesis of tyrosine, it is best to consider both the phenylalanine and tyrosine content of the diet in any attempt to evaluate the indispensable amino acid supply. Similarly, cystine may be used in place of part of the methionine, so that these two sulfur-containing amino acids should be considered together.

The data in Table 6 illustrate the variation in the minimum quantity of various proteins needed to maintain the tissue proteins in an adult dog (1, 2, 3, 4, 5, 6, 7, 8, 93, 104). The minimum for each dietary protein will vary somewhat according to the source. For example, not all fish meals will have as high a nutritive value as the sample used to obtain the data recorded in Table 6. Some samples of beef may have a higher nutritive value, etc. All of the proteins recorded in this table were well digested, so that amino acids supplied to the body by the protein could be estimated from chemical analyses.

Of all the proteins tested, egg protein is needed in minimum amount to maintain nitrogen equilibrium in the adult dog. The assumption is made, therefore, that egg protein supplies the indispensable amino acids in approximately the correct amounts and ratios for the metabolic needs of the body. The "biological value" of egg protein is used as an index of 100 since practically all of the nitrogen in egg protein is retained in the body for tissue protein synthesis (104). Larger quantities of other proteins are needed

# TABLE 6

**Grams of Different Dietary Proteins Required Per Pound Body Weight to Maintain Nitrogen Equilibrium in the Adult Dog, and Milligrams of Amino Acid Supplied By These Quantities of Protein**

| | PROTEIN REQUIRED PER LB BODY WEIGHT PER DAY IN GM | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | Egg 0.57 | Fish meal 0.62 | Beef 0.73 | Casein 0.73 | Casein and methionine 0.57 | Peanut flour 1.02 | Wheat gluten 1.41 | Wheat gluten and lysine 0.71 | Minimum values 0.57 |
| | Milligrams of amino acid supplied by above amounts of protein | | | | | | | | |
| Arginine | 34 | 43 | 47 | 30 | 22 | 113 | 52 | 26 | 22 |
| Histidine | 10 | 11 | 23 | 23 | 17 | 23 | 28 | 14 | 10 |
| Isoleucine | 36 | 32 | 38 | 50 | 36 | 42 | 63 | 32 | 32 |
| Leucine | 50 | 48 | 57 | 78 | 57 | 72 | 102 | 51 | 48 |
| Lysine | 40 | 55 | 53 | 62 | 46 | 35 | 31 | | 31 |
| Phenylalanine | 33 | 23 | 29 | 42 | 31 | 50 | 71 | 36 | 23 |
| Tyrosine | 19 | 16 | 22 | 40 | 29 | 29 | 40 | 19 | 16 |
| Phenylalanine + Tyrosine | 52 | 39 | 51 | 82 | 60 | 79 | 110 | 55 | 39 |
| Methionine | 23 | 18 | 20 | 25 | 27 | 9 | 23 | 12 | 9 |
| Cystine | 17 | 9 | 10 | 3 | 3 | 15 | 33 | 17 | 15 |
| Methionine + cystine | 40 | 27 | 30 | 28 | 30 | 24 | 56 | 29 | 24 |
| Threonine | 28 | 28 | 32 | 35 | 25 | 29 | 40 | 20 | 20 |
| Tryptophan | 7 | 7 | 7 | 7 | 6 | 8 | 10 | 6 | 6 |
| Valine | 42 | 32 | 38 | 57 | 42 | 47 | 61 | 30 | 30 |

to meet the requirements for maintenance because they have a relative deficiency in the quantity of one or more of the indispensable amino acids.

For example, casein, which is not rich in sulfur-containing amino acids, is required at a level of 0.74 gm, as compared to 0.57 gm of egg protein. Supplementation of casein with methionine increases the biological value (1, 5).

In general, if the biological value is 60 or greater, the protein will be adequate to meet the needs for maintenance or growth although the amount provided by the diet must be increased as the biological value decreases (6). This value can be estimated for the dietary proteins in Table 6 by dividing the requirement of egg protein for maintenance by the value for the dietary protein, and multiplying by 100. The biological value, for example, for wheat gluten is approximately 40 (0.57/1.41 x 100). Wheat gluten does not provide for adequate growth even though the intake is increased in an effort to overcome the deficiency in indispensable amino acids (6). Lysine is the principal deficiency in wheat gluten; hence adding this amino acid increases the nutritive value.

Ordinary diets, however, are made up of a mixture of dietary protein sources. One protein may tend to supplement another so that the biological value of the mixed protein in a diet cannot be estimated from biological values of the individual dietary proteins. Two proteins, each with a low biological value, when mixed, may supplement each other so that the mixture will have a high value (67). If adequately digested, however, the value of the mixed diet can be estimated from analyses for the indispensable amino acids. The closer these amino acids come to the amounts and proportions recorded in the last column of Table 6, the higher the nutritive value.

The values recorded in Table 6 are minimum for maintenance in the normal adult dog. These quantities decrease if the dog is depleted in certain tissue proteins which are sometimes called "labile reserves." Plasma albumin is such a reserve. The dog adapts to a reduced protein intake so that less protein is needed for maintenance. If the intakes, however, are much below the values recorded in Table 6, the dog is probably being maintained in a depleted state (4, 76). Indeed, to meet various stresses, the protein intakes should be somewhat greater than the values given in this table. Possibly a good working rule would be to provide at least 12 per cent of the kcal in the form of a good quality protein, increasing this percentage if the quality is reduced.

The dietary protein intake needed for growth is greater than the amount required for maintenance (58, 92). A Beagle puppy, when just weaned, for example, needed approximately 2.4 gm of protein per day per pound of body weight. At 10 weeks of age, this value had dropped to approximately 1.3 gm of a high-quality protein per pound of body weight (7). Since caloric intake also is high during growth, these protein requirements for growing dogs can be met when high-quality protein supplies 12 per cent of the kcal of the food. If the biological value of the protein is less than 60, it should be improved in nutritive value rather than increased in quantity, in an effort to overcome amino acid deficiencies.

The protein requirements during pregnancy and lactation are well above the maintenance levels (112). Indeed, the lactating dog may well require double the maintenance quantity of protein (111). However, since calorie requirements also go up rapidly, a diet which provides adequate protein for maintenance will usually also be adequate for these periods if fed in adequate amounts.

Since most diets include a variety of proteins, some of which do not have high biological values, practical feeds usually include sufficient protein to supply 20–25 per cent of the kcal. That this amount is needed is suggested by the report of Heiman (68) which stated a dry ration containing 15 per cent protein (largely from soybean, meat, and fish meals) did not permit optimum growth of cocker pups, but that a ration containing 20 per cent protein supported good growth. Assuming 1,560 total kcal per pound for the air-dried feed, the 15 per cent and 20 per cent levels of protein would correspond to 17 per cent and 23 per cent of the kcal. In view of the use of soybean and fish meals as the sources of protein, it would seem that 20 per cent of the kcal should be considered a minimum for practical mixed diets to be used with growing dogs. Since the caloric need per pound of body weight of adult dogs is less than that of growing dogs, this is a reasonable allowance for maintenance, although lower levels may suffice in some cases.

If fat does not constitute more than five per cent by weight of the dry matter of the feed, protein levels of 22–25 per cent of the solids will supply 20 per cent of the kcal. Feeds that contain higher levels of fat will require more protein, sometimes as much as 30 per cent (92).

Digestibility is an important factor in considering protein in feeds. Usually the better-quality proteins are well digested and absorbed, and they favorably influence the digestion and utilization of other less readily digestible proteins (67). In mixed dry-type rations supplying an adequate amount of protein, from 70 to 80 per cent of the protein may be expected to be digested and absorbed (67, 73). Moderate heat treatment of ingredients, particularly if moisture is present, does not reduce the value of proteins; but excessive heating may cause partial destruction of certain of the essential amino acids (12).

## *Carbohydrate*

It has not been demonstrated that dogs have any specific requirement for carbohydrate. However, in practical diets, carbohydrates have an important role, chiefly as a source of calories. The dog can efficiently utilize large amounts of carbohydrates in properly balanced diets.

Numerous investigators have used high levels of starch, dextrin, or sugars in experimental rations and many animals have been maintained for long periods of time upon breads or other cereal products (92). It appears that a maximum of 65 per cent of appropriate carbohydrate (dry basis) is practical to allow for sufficient protein, fat, and minerals, and this value has been selected as the maximum for complete foods.

The dog is able to digest and absorb starch and glucose (72, 73, 124). Excessive amounts of lactose (milk sugar) will produce diarrhea. Ivy, Schmidt, and Beazell (72) report the ability of the dog to utilize diets containing as much as 81 per cent cooked cereals. Both raw and cooked carbohydrates are utilized (92, 123, 124), although McCay (92) reports development of diarrhea if a high dietary level of raw starch is supplied for several days. Thus, starches or cereals should be processed by baking, cooking, toasting, or other means for most satisfactory use as dog-food ingredients.

Certain types of carbohydrate supplements such as dried beet pulp, tomato pomace, and the bran layers of some seeds are poorly digested by the dog, but when used at low levels they have a "bulking" effect on the feces. Fiber, which occurs as part of many carbohydrate-rich foodstuffs, has a similar effect. It, also, is nondigestible. At reasonable levels, these indigestible carbohydrates and fiber do no harm. High-fiber products are not normally used in dog foods.

## *Fat*

Some fat is essential in the diet of dogs for normal health (65). Fat-deficient dogs develop dry hair, dry, scaly skin, and are susceptible to infections of the skin. These are usually resistant to external treatment but respond well to dietary supplements of fat (64).

The minimum fat requirements for dogs have not been established. It is likely that the need would vary depending on the essential fatty acid content of the fats used. Hansen and Wiese (66) have reported that the fatty acids probably responsible for producing the favorable effect on dog health are linoleic and arachidonic acids. These workers also noted that fat-deficiency symptoms were not completely and permanently eliminated where lard comprised less than 15 per cent of the dietary kcal. More recent work has indicated that linoleic acid should supply at least two per cent of the energy of the ration. This would approximate 0.7 per cent of the dry solids of a typical ration.

Many dogs have been maintained successfully on dry rations which contain five to eight per cent fat. On a dry-matter basis, canned rations have an average fat content of 10 per cent or more (83). Morgan (106) satisfactorily fed diets containing 24 per cent fat for two years. Axelrod *et al.* (17), successfully fed fat at a 40 per cent level to growing cocker spaniels. Ivy (71) also maintains that dogs can tolerate 40 per cent fat in the diet. Thus, it appears that the dog has a rather wide tolerance for fat.

One of the cautions to observe in feeding of high-fat diets is to adjust protein, minerals, and vitamins to maintain proper nutritional balance. Campbell and Phillips (24, 114) found that high fat levels in the diet caused reduced food intake and retarded growth of puppies. This was corrected by adding methionine to balance amino acid requirements.

Levels of five per cent (87) and 11 per cent (42) of fat have been suggested as goals for commercial dog foods. Siedler and Schweigert (137, 138) showed that four per cent or eight per cent choice white grease added to a diet already containing 3.7 per cent fat produced satisfactory growth in Cocker Spaniel puppies. Reproductive performance was somewhat better for bitches receiving four per cent added fat (total 7.7 per cent), but, at eight per cent added fat reproductive performance, may have been slightly impaired. The committee has selected five per cent fat as required for dry food since this level appears sufficient for normal physiological function. Use of higher levels is considered desirable in practical nutrition.

Fats supply essential fatty acids needed for adequate nutrition. They furnish a concentrated source of energy since they contribute 9.3 kcal per gm compared with 4.1 from carbohydrates and proteins (33). Fat also contributes to the palatability and texture of dry dog foods.

Development of rancidity in dog-food fat is undesirable, especially because of its well-known destructive effect on fat-soluble vitamins. Use of an anitoxidant is therefore recommended (110) to retard rancidity.

## *Minerals*

Dogs require calcium, phosphorus, iron, copper, potassium, magnesium, sodium, chlorine, iodine, and probably also manganese, cobalt, and zinc. Estimates of the exact requirements are not possible because of the paucity of data. Many of the values commonly found in the literature for dog rations have been computed from the known needs of other species.

The close relationship of calcium and phosphorus suggests that they be considered as a unit. A calcium-to-phosphorus ratio of 1.2:1 is considered best for maximum utilization of these minerals and also of vitamin D. This is in close agreement with ratios found to be satisfactory for other species (27, 28, 29, 30, 31). Availability of these nutrients must be considered, since it is well known that diets high in phytates, or low in vitamin D, adversely influence the absorption of calcium (70, 101).

The amount of calcium and phosphorus retained varies with age; rapidly growing puppies need the most generous supply. Hoff-Jorgensen (70) found that even when one gm of each of these minerals was supplied to small puppies daily, only 0.2 to 0.3 gm was retained. The amount absorbed and retained was fairly constant during the first 200 days of age despite an approximate six-fold increase in body weight. There was a tendency for retention to be slightly higher during the third and fourth months than at other periods in the growth cycle. The highest retention of calcium observed by Hoff-Jorgensen was 73 mg per pound body weight per day. Retention of 35 mg per pound per day was more common. Addition of phytic acid to the ration decreased absorption and retention of calcium but increased absorption and retention of phosphorus. This is possibly due to the precipitation of calcium as the insoluble calcium phytate.

Morgan (105) reported that rations supplying approximately 0.50 per cent of calcium and 0.65 per cent of phosphorus permitted normal bone development in some animals which were supplied with vitamin D. Others, chiefly large breeds, developed mild symptoms of rickets when the calcium intakes were between 45 and 80 mg per pound body weight daily. Retentions varied from 19 to 41 mg, except for one dog which retained as much as 54 mg per pound daily. As might be expected, these retentions are lower than those found with rations higher in calcium by Hoff-Jorgensen.

The retentions reported by Hoff-Jorgensen; namely, 200 to 300 mg per day per dog, regardless of weight, are in good agreement with values obtained by Udall and McCay in young Beagles receiving calcium and phosphorus in the form of fresh bone (151).

Jenkins and Phillips (75) found growing puppies required 0.37 per cent of available calcium (0.60 per cent of total calcium in the ration) for satisfactory growth, normal development, and well-mineralized skeletal structures. High levels of dietary fat failed to influence the calcium requirement. These studies would indicate that approximately 0.75 per cent of total calcium in the ration would suffice if one assumed a 50 per cent availability. An assumption of 50 per cent availability may not cover all situations, however, since Morgan (105) found retention values ranging from 40 to 70 per cent. On the other hand, McCay (92) noted 60 to 80 per cent utilization of the calcium in the rations he used.

Calcium that is not utilized is excreted mainly in the feces. There is no evidence that a calcium level of 1.0 per cent, or even higher, in the ration produces any harmful effects if the proper calcium-to-phosphorus ratio is maintained. From a practical point of view, the extensive studies of Koehn (80) deserve mention. A ration composed largely of cereal grains or grain products and containing 2.25 per cent of calcium and 1.55 per cent of phosphorus was extensively tested under practical hunting conditions and found to be entirely satisfactory. For reproduction in foxhounds, this ration was rated as somewhat better than the other meal-type rations which were somewhat lower in calcium and phosphorus content.

The salt mixture of Phillips and Hart (115) at a level of four per cent in the ration has supplied the mineral requirements of dogs under experimental conditions over a period of years. This provides approximately 0.5 per cent of calcium in the ration, or about 60 mg per pound body weight daily for adult dogs and twice this amount for puppies.

Requirements for phosphorus are even less well defined, although it has been demonstrated repeatedly that rations low in phosphorus lead to poor calcification of bones and other symptoms or rickets.

Morgan (105), using intakes of 45–80 mg per pound body weight daily (average 62), obtained retentions of 12 to 43 per cent (average 23 per cent) of the phosphorus. Hoff-Jorgensen (70), with more liberal intakes of one gm of phosphorus per day, reported retentions of 18 to 38 per cent. The requirement for phosphorus was established by Jenkins and Phillips at 0.33 per cent in a practical-type ration (74). Under these conditions, a 76 per cent retention was observed, which would indicate a minimum need of 0.25 per cent of available phosphorus in the ration. In these studies about 45 per cent of the phosphorus was present as phytin phosphorus, and calcium was present at a level of 0.60 per cent. The phosphorus requirement increased slightly, by 10 to 15 per cent, when the calcium was increased to 0.9 or 1.2 per cent (75). High levels of dietary fat increased the phosphorus requirements about 20 per cent.

Based on these observations, the requirement for phosphorus would be met under normal conditions if the ration contained 0.5 per cent of total phosphorus and if one assumes a 50 per cent availability.

If one assumes a 50 per cent availability of calcium and phosphorus, the requirement suggested in Table 1 (1.0 per cent of calcium and 0.8 per cent of phosphorus) would furnish 120 mg of available calcium and 96 mg of available phosphorus per pound body weight per day for growing puppies and about one-half these amounts for adult dogs. This represents some excess over the requirements as found by Jenkins and Phillips (75) and (11). This excess amounts to about 30 per cent in the case of calcium and slightly more than this in the case of phosphorus. Such a margin of safety for estimating requirements for various types and breeds of dogs, many of which have not been subjected to careful study, would appear to be reasonable, particularly in view of the presence of factors that might adversely influence the utilization of these minerals in many practical-type rations. It should also be clear that some types and breeds of dogs would no doubt perform satisfactorily on somewhat lower intakes of these minerals. The study of Gershoff *et al.* (57) has revealed that the dog can adapt to low calcium intakes much like other species thus far studied. These workers maintained two dogs for 31 months on a synthetic ration containing only 0.11 per cent calcium. The dogs were two to three months old, however, when subjected to the low calcium intake, a stage in growth that may be less critical for bone-building minerals than that of weanling, six-week-old puppies. Also, a 90 per cent utilization of the dietary calcium was observed, a level which is generally not achieved with practical rations.

Iron and copper have been shown to be essential in the diet for the prevention of anemia (55, 117). Ruegamer *et al.* (126) were able to maintain a normal hemoglobin level in a collie pup which was receiving 1.36 mg of iron (as ferric pyrophosphates) per pound of body weight per day. Other puppies, made anemic by an iron-free diet, did not make recoveries when 182 mcg of ferric pyrophosphate per pound were supplied daily, but did recover satisfactorily when the supplement was increased to 273 mcg per pound (equivalent to 92 mcg of iron). When the supplement was increased to 450 mcg, more iron was absorbed and utilized, but the percentage of utilization dropped from about 60 per cent (273 level) to about 36 per cent (450 level). One dog receiving 182 mcg of the supplement utilized 74 per cent of the iron, but the intake was inadequate even though it was more efficiently utilized. Others (55) have also obtained 60 to 70 per cent utilization of inorganic-iron supplements, and have indicated that absorption may approach 100 per cent in some cases. At the 273 mcg level, normal values of 100–200 mcg of iron per 100 ml of plasma were found. With the smaller supplements, plasma iron values were low.

Based on these figures it would seem that 600 mcg of dietary iron per pound of weight should adequately supply the needs of the growing puppy or the dog which is rebuilding blood, as well as of the normal animal. Even if all of this originated from inefficient sources, it would correspond to about 300 mcg absorbable iron per pound, which is above the level found to be adequate for hemoglobin regeneration (126). If much of this iron came from soluble inorganic salts, the allowance might be reduced, but lack of adequate information on the effect of other dietary constituents on iron makes this seem inadvisable. McCance and Widdowson (91) in their review of this subject indicate that a number of substances, such as phosphates and phytates, may depress utilization of dietary iron. Likewise, insoluble iron salts and certain slightly soluble ones are not well utilized. Since excesses of iron are eliminated unabsorbed (91) it is preferable to feed an amount sufficient to allow for poor absorption or for interference by other dietary components. The allowance suggested, 600 mcg per pound of dog per day, is slightly in excess of that provided by the widely used Phillips and Hart formula (115). However, the reports of satisfactory performance of dogs fed this formula have been made primarily when refined diets were used rather than mixtures of natural foodstuffs which might contain more interfering substances.

The iron of bran has been shown to be as available as that of ferric pyrophosphate, but that of spinach was less than half as effective (55). This conforms with the relative availability of the iron in those three materials when fed to rats and suggests that availability data for the rat may be used as a guide for dogs. Sherman, Elvehjem, and Hart, and others (45, 46, 136) have shown the iron of inorganic salts, liver, heart, muscle, and soybeans to be readily available (50 per cent or more utilized) while that of oysters, alfalfa, spinach, blood, wheat, oats, and yeast was less efficient (25 per cent utilized).

Frost, Elvehjem, and Hart, and Linton (55, 87) demonstrated the necessity of copper for the incorporation of iron into hemoglobin. Without copper in the diet, iron was absorbed but hemoglobin was not formed efficiently. With two mg of copper per day per dog, hemoglobin formation proceeded normally. Since this amount adequately supplied dogs weighing up to 29 lbs, despite the fact that they were under the strain of growth or hemoglobin regeneration, an amount of 75 mcg per pound per day should be adequate and has been tentatively accepted as the recommended allowance. However, there is no direct evidence that 75 mcg per pound is adequate for small rapidly growing puppies.

Frost and Elvehjem (54) reported that cobalt at a level of 0.1 mg per dog also stimulated hemoglobin production. One-half mg per day along with 2 mg of copper and 10 mg of iron, used in a more detailed study by Frost, Elvehjem, and Hart (55) provided for more efficient conversion of iron to hemoglobin than did iron and copper alone. However, these same authors reported that under certain conditions cobalt hinders production of hemoglobin and produces abnormal blood cells.

Stanley and his associates (142) injected 1.1 to 4.5 mg of cobalt per pound of weight into rats for 8 months and throughout this range produced abnormalities in the blood volume and cell sizes. They concluded, however, that these results did not indicate serious toxicity. The level of 0.5 mg of cobalt per dog used by Frost *et al.* (55) amounted to approximately 25 mcg per pound of body weight, and is assumed to be an effective dose and not an excessive amount.

Normally, diets that are not especially prepared from pure ingredients contain sufficient sodium, potassium, chlorine, iodine, and other minerals to prevent deficiencies. However, by feeding purified low-potassium rations to dogs, Ruegamer, Elvehjem, and Hart (125) obtained poor growth, restlessness, and paralysis of the neck and fore part of the body. Administration of a three-gm dose of potassium chloride and inclusion of the salt in the diet at a level of 0.6 per cent relieved these conditions and permitted normal growth. This amount is equivalent to 0.32 per cent potassium in the diet and provided 30 mg of potassium per pound of body weight. Some additional potassium was also provided by the diet. The ration was composed of highly digestible foodstuffs, providing five kcal per gm, and was fed at a level of 10 gm of diet per pound of dog.

Potassium requirements for the rat are 0.18 per cent in the ration for growing young and 0.15 per cent for the adult. Gillis (59) found that 0.20 to 0.24 per cent dietary potassium permitted maximum growth in chicks. Since chicks frequently have a higher requirement than mammals for nutrients, one would expect this level to be adequate for dogs. On a calorie basis, this would provide even less than Ruegamer's ration. In lieu of a more adequate demonstration of required amounts, a slightly higher level, 100 mg of potassium per pound of body weight, is suggested as a minimum to be provided. This amount is considerably under the 240 mg per pound provided by the Phillips and Hart salt mixture, but that mixture was intended to supply generous amounts and no data regarding potassium requirements were available when it was devised.

No specific minimum can be set at this time for sodium chloride or for sodium and chlorine as other salts, and there is little evidence that serious deficiencies of either of these ingredients will occur when natural foodstuffs are fed. However, sodium and chlorine, along with potassium, are essential for normal physiological performance and must be supplied either in the other foodstuffs or as sodium chloride. It is known that salt deficiency in humans results in fatigue and exhaustion, and McCance (90, 91) has shown that prolonged deficiencies result in lower protein efficiencies. McCay (92) in reporting experiments with diets containing two per cent added salt, commented that the dogs consumed more water than usual but remained in good health. One and one-half per cent of total sodium chloride (dry solids) should supply normal needs and is not an excessive allowance. Accordingly, this had been designated as an appropriate level. This would amount to approximately 0.15 gm of sodium chloride or 59 mg of sodium and 91 mg of chlorine per pound of body weight. On less efficient rations, the intake would be higher. The sodium requirement of the rat is 0.7 per cent (114).

Small amounts of iodine are required by dogs for prevention of goiter (100). Salt mixtures supplying two mg of iodine per pound of diet have proved satisfactory (115). Inclusion of iodized salt (.007 per cent iodine) in dog diets has also been shown to be an effective preventative of iodine deficiency. Since the use of iodized salt has proved effective with many other species as well as with the dog, incorporation of one per cent iodized salt in dog diets should meet requirements. High amounts of iodine are toxic and must be avoided.

There is little information available on the quantitative requirements of dogs for manganese, magnesium, and zinc. These minerals do occur in the animal body, however, and magnesium and manganese, at least, play a role in catalyzing certain metabolic reactions. Accordingly, it is common practice to include small amounts of these minerals in diets for all animals. The amounts required are obviously small and the levels used in the salt mixture of Phillips and Hart (115) seem to be adequate. Accordingly, these have been adopted, although it is recognized that proof of the need for these amounts is lacking.

## *Vitamins*

Certain vitamins have been recognized for over 40 years as essential nutrients for dogs, yet, despite many investigations, the actual levels needed are uncertain. This is at least partly due to the interrelationships between the vitamins and other nutrients and to the variations in requirements as the percentages of the protein, fat, carbohydrate, and mineral components are varied.

In addition to these known vitamins for which requirements are discussed in some detail below, there is evidence that other known vitamins and some factors of unknown nature may be important in dog nutrition. These other materials, however, can be demonstrated to be essential for dogs only under specialized conditions and have little immediate practical significance. Balanced rations composed of natural feedstuffs will normally contain enough of these non-critical materials to assure diets adequate in this respect. For the better-known vitamins it is possible to estimate levels which are adequate.

## *Vitamin A*

Vitamin-A deficiency was among the first vitamin deficiencies to be recognized. Steenbock in 1921 (143) reported that dogs deprived of "fat soluble vitamins" developed typical symptoms of xerophthalmia. Others (53, 102, 127, 144) have shown the first symptoms in dogs to be loss of appetite, poor growth, and weak and infected eyes. Respiratory infections are caused by severe and prolonged deficiency of vitamin A and frequently result in the death of the animal. In adult dogs, symptoms develop slowly, and mild deficiencies may not be recognized (35, 79). Other work has indicated that this deficiency results in changes in the blood picture, primarily in a lag in the neutrophile index (35) and a degeneration of certain nerves (101). Large doses of vitamin A are reported to relieve certain types of experimentally produced hypertension (78, 153). Clinically, low levels of vitamin A (79) in blood plasma and changes in the neutrophile index (35) are early danger signs.

On the basis of the vitamin-A requirements of other species, Michaud and Elvehjem (103) estimated that nine mcg of vitamin (30 IU) daily per pound of body weight was adequate for growing dogs. Others, however, have shown that larger amounts are necessary in order to permit storage of vitamin A in the liver. Bradfield and Smith (22) were able to raise young puppies for periods up to 22 weeks when vitamin A was provided daily at a level of 91 IU per pound of body weight, with no appearance of deficiency symptoms, but with storage of only slight amounts of vitamin A in the liver. When the supplement was increased five- or tenfold, appreciable storage in the liver occurred. The dogs receiving the higher levels of vitamin also had more lustrous coats than paired animals fed the ration supplying 91 units per pound of body weight. Frohring (52, 53), using a vitamin A-deficient synthetic "milk" which permitted excellent growth of puppies when supplemented with adequate amounts of vitamin A, was able to demonstrate that puppies on the deficient diet lost approximately 45 IU per pound daily. This is at the upper end of the range of utilization rates found by Crimm and Short (35). Replacement of this amount as a curative dose failed, however, and the level had to be increased to 90 units (carotene) daily per pound of body weight before growth was resumed.

These data indicate that provision of 90 IU of vitamin A per pound of body weight daily is adequate for the growing dog. While older dogs may require less for metabolism, their absorption rate is much lower, and provision for a similar amount in the diet might be advisable. However, the fact that adult dogs can exist for long periods without showing deficiency symptoms and have been known to raise several litters while on a deficient ration makes it appear that adults have a lower requirement.

A number of investigators (22, 35, 52, 143, 150) have shown carotene to be an effective source of vitamin A for the dog. Although the dog can use carotene, its ability to transform carotene to vitamin A and to store the surplus thus formed, appears to be limited. On high vitamin-A intakes, dogs may show extraordinarily elevated serum vitamin-A levels, large liver stores, and constant urinary excretion of vitamin-A alcohol (108). No other animal species has been reported to excrete vitamin A in the urine. Large carotene dosage, however, does not produce the high serum and liver levels or urinary vitamin-A excretion.

## *Vitamin D*

Vitamin D, phosphorus, and calcium all play a role in the prevention of rickets, and their effectiveness depends upon proper amounts of each nutrient. Deficiencies of vitamin D are most common in rapidly growing puppies which develop rickets readily. There is some doubt that adult dogs exposed to even moderate amounts of sunshine require dietary vitamin D (92). Large, heavy-boned breeds are most sensitive to deficiencies because of their great need for calcium and phosphorus for bone formation. Vitamin-D deprivation markedly impairs Ca transport (129). In rickets, bones are not properly calcified and bend or "bow" readily. Teeth are irregular and slow to erupt. Blood levels of calcium and phosphorus are altered, but the extent of these variations depends upon the amount of minerals in the ration, as well as upon the lack of the vitamin.

Minimum effective allowances reported in the literature range from the 0.45–0.60 IU per pound of body weight (82) to over 115 IU per pound of body weight for Great Dane dogs (48). Arnold and Elvehjem (11) were able to protect an Airedale with less than six IU per pound of body weight, and this amount was adequate even for Great Danes when the calcium-phosphorus ratio was 1.2:1. With ratios of 2:1, bone calcification was poor unless large amounts of vitamin D were used. Michaud and Elvehjem

(103) reported that nine IU of vitamin D per pound of body weight was adequate for many dogs in their experimental colony. Much lower amounts should be adequate for adult maintenance but not for pregnancy or lactation.

Massive doses of vitamin D or prolonged administration of high levels may lead to calcification of the soft tissues, excessive mineralization of the bones, and deformation of the teeth. Growth is apt to be poor, and anorexia, polyuria, bloody diarrhea, excessive thirst, and prostration may result (69, 107, 109). Doses producing these results are far above normal feeding levels, however, and need not deter liberal use of vitamin D in the ration.

## *Vitamin E*

Although it has not been proved definitely, there is evidence that the dog requires vitamin E for normal reproduction and lactation. Anderson *et al.* (9, 10, 44) devised a vitamin E-free diet which supported normal growth and maintained dogs satisfactorily. Reproduction and lactation, however, were poor. Young were born weak or dead, and those living suffered from muscular dystrophy and other symptoms associated with vitamin-E deficiency in rats. Addition of vitamin E to the diet at a level to supply 0.45 mg per pound of body weight per day improved reproduction and lactation, but some signs of muscle dystrophy were still observed. Schaefer (132) suggests the use of 10 mg of tocopherols per pound of diet. However, vitamin E is subject to destruction by oxidation, particularly if fat in the diet becomes rancid. Hence, for growth, 20 mg of vitamin E per pound of dry diet is recommended.

## *Vitamin K*

Under normal conditions, the dog seems either not to require dietary vitamin K or to be able to synthesize vitamin K in the gut. Quick (118), using dogs with a cholecystonephrostomy, observed that 0.5 mcg of vitamin $K_1$ per Kg was required to maintain a normal prothrombin level. He found that the oral administration of vitamin K will elevate prothrombin time in the absence of bile (118). Based on this, the vitamin-K requirement seems to be seven ppm in the solids of the total ration under these special conditions.

## *Thiamine* (Vitamin $B_1$)

The need of the dog for thiamine in the diet was recognized early in the history of vitamins. Characteristic deficiency symptoms are anorexia, loss of weight, paralysis, convulsions, decreased ability to respond to conditioned reflexes (113), and impaired gastric secretion (32, 77, 85, 152). Cures can be effected readily with any good source of thiamine. Cowgill (34) reported that a daily dose of 2.7 mcg of thiamine per pound of body weight was sufficient for mature dogs. Street (149) estimated the requirement to be 3.0 to 4.3 mcg per pound of body weight. Arnold and Elvehjem (11, 12) reported that nine mcg per pound of body weight maintained growth, a finding supported by Maass *et al.* (89).

The composition of the diet influences thiamine requirements, high-fat diets requiring less thiamine than those high in carbohydrate (13). Metabolic disturbances may also influence requirements, as has been shown by the appearance of thiamine deficiencies during feeding of a normal diet plus thyroid (13, 38, 39, 40). For ordinary diets, however, six to eight mcg of thiamine per pound of body weight daily should supply the requirements of the adult dog. During growth, pregnancy, or lactation, approximately twice this amount may be needed.

## *Riboflavin* (Vitamin $B_2$)

Acute riboflavin deficiency frequently results in collapse of the animal (146), accompanied by a fall in temperature, a variable heart rate, and a low respiratory rate. Dogs in this condition invariably die unless promptly injected with riboflavin. Chronic deficiency results in loss of weight, weakness, and frequently diarrhea. Watery eyes and bloodshot eyeballs also appear in some cases. If continued, fatty livers and corneal opacities occur. Administration of riboflavin promptly relieves these symptoms.

Mature dogs can be maintained with 11–12 mcg of riboflavin per pound of body weight (146, 148). Levels of 23 to 45 mcg are required by growing dogs (15, 16, 116, 141). When all other nutrients are available, the use of 27 to 45 mcg has proved satisfactory for growing puppies (116). The use of 45 mcg is in fair agreement with the finding that 0.9 mg of riboflavin per pound of ration is needed to permit storage of riboflavin (16). A level of 20 mcg of riboflavin per pound of body weight should supply the requirements of the adult dog. Twice this amount should be sufficient for growing puppies.

## *Niacin* (Nicotinic Acid)

Blacktongue or canine pellagra ordinarily occurs only in areas where corn forms a major part of the diet of both man and dog. It is commonly noted in the pets of families where pellagra is prevalent. Distortion of conditional reflexes and disturbance of the nervous system occur prior to the appearance of typical symptoms (43). The disease is characterized by sensitivity of the mucous membranes of the mouth, and by a sore purplish-black tongue if the deficient diet is continued. Emaciation results, and eventually the dog dies from the disease unless niacin or high-quality proteins are supplied. These latter provide tryptophan from which niacin may be synthesized by the tissues or microflora of the intestinal tract. Ordinarily, niacin deficiencies are accompanied by deficiencies in riboflavin, thiamine, and other vitamins of the B complex (36, 81, 84, 86, 98, 99, 128, 140, 154). Hence, treatment usually involves an improvement in the diet and supplementation with a rich source of the B vitamins. Niacin alone in doses as low as 0.3 mg per pound body weight daily has been shown to relieve the symptoms promptly (99), although higher levels usually have been used (135, 145).

Requirements are the highest when the ration is rich in corn (63, 84); hence, allowances sufficient to supplement adequately the Goldberger diet (60) should suffice to meet all normal dietary needs. Schaefer *et al.* (132), with a Goldberger diet supplemented by B vitamins other than niacin, showed that 115 to 165 mcg of niacin per pound of body weight per day prevented symptoms in puppies. Adult dogs required 91 to 102 mcg per pound of body weight per day. These values are in accord with the requirement of 115 mcg per pound of body weight per day reported by Birch (19) who also showed that 59 mcg per pound of body weight per day prevented deficiency symptoms and allowed slow growth. Dann *et al.* (37) were able to prevent symptoms by providing 68 mcg of niacin per pound of body weight per day. Handler (63) was unable to demonstrate the onset of typical blacktongue symptoms when a purified diet containing casein was used, although it supplied niacin at a level of only five mcg per pound of body weight per day. These data all indicate that 110 mcg of niacin per pound of body weight per day should be sufficient to give protection to adult dogs with any ordinary diet. To insure protection of puppies, the level should be raised to 180 mcg per pound. Tryptophan can take the place of part of the niacin. The niacin in corn is relatively unavailable and should not be considered as part of the niacin supply.

## *Pantothenic Acid*

Growing dogs need pantothenic acid, but the amounts required and the function of the vitamin are still not well known. Deficient dogs have erratic appetites, intestinal disorders, and poor growth. Convulsions, collapse, and coma are symptomatic in severe cases (93, 139). Liver damage also may be extensive (134). Schaefer *et al.* (131) were unable to raise puppies on a diet supplying 27 mcg of pantothenic acid per pound of body weight per day, but were able to avoid deficiencies with 45 mcg. Accordingly, the latter level appears to be as satisfactory as can be established at this time for puppies. It is probable that adult dogs require much less, and the level suggested is one-half that for puppies.

## *Vitamin $B_6$* (Pyridoxine)

Deficiencies of vitamin $B_6$ result in microcytic hypochromic anemia (50), failure of the heart to function properly, degeneration of nerves (147), and the appearance of convulsions. Vitamin $B_6$ or pantothenic-acid deficiency in dogs causes a loss of conditional reflex performance comparable to loss of mental function in man. This loss appears 4–10 days before neurological symptoms or blood alterations. This effect is reversible (56). As in many deficiencies, there is usually loss of appetite, poor growth, and diarrhea. The anemia cannot be cured by supplementation with iron and copper, but responds well to pyridoxine.

Birch *et al.* (20) showed that the vitamin-$B_6$ complex consisted of three factors and that vitamin $B_6$ was distinctly separate from the anti-blacktongue factor and lactoflavin. Fouts *et al.* (51) showed that vitamin $B_6$ was necessary for blood regeneration and normal growth in young puppies. These workers (51) also reported that the addition of 27 mcg of vitamin $B_6$ per pound of body weight per day cured microcytic hypochromic anemia. However, some evidence was presented indicating that some other unidentified component of the vitamin-B complex was needed for complete recovery. Borson and Mettier (21) also reported that 27 mcg of synthetic vitamin $B_6$ per pound of body weight per day relieved the microcytic hypochromic anemia developed on vitamin $B_6$-deficient diets, but crude concentrates of vitamin-B complex had to be used for complete blood-picture restoration. McKibbin *et al.* (95, 96) used crude liver extracts to obtain complete elimination of the anemia. Dogs kept for several months on semi-purified ration without added pyridoxine developed hypochromic anemia and became subject to epileptic seizures. For complete recovery, 90 to 220 mcg per pound body weight per day was necessary. Michaud and Elvehjem (103) obtained fairly good growth with pups fed five mcg vitamin $B_6$ per pound of body weight per day, but better growth was obtained when 27 mcg were provided. They concluded that the vitamin-$B_6$ requirement for growth lies between five and 27 mcg per pound of body weight per day. For mature dogs, a daily intake of five mcg per pound of weight suffices. Vitamin $B_6$ functions in the metabolism of protein, and rations high in protein require extra $B_6$ for complete protection (18).

The limited data regarding vitamin-$B_6$ requirements of dogs indicate that the normal requirement is 10–25 mcg per pound of body weight per day.

## *Folic Acid*

Ordinarily dogs do not need folic acid in the diet, but Afonsky (2) has reported one case in which folic-acid deficiency was produced with a semi-purified ration. The hemoglobin concentration decreased and hematrocit values dropped from 49 to 33. Administration of seven mcg of folic acid per pound body weight brought about a maximal response. Schaefer recommends 135 mcg of folic acid per pound of diet and 67 mcg for maintenance (132). Practical rations provide adequately for this vitamin without supplementation, according to present reports.

## *Vitamin $B_{12}$*

Vitamin $B_{12}$ is necessary for growth and blood regeneration, but, under ordinary circumstances, the diet contains $B_{12}$ or permits sufficient intestinal synthesis of the vitamin to prevent deficiencies. Arnrich *et al.* (14) were able to get good growth of Cocker Spaniel puppies without adding vitamin $B_{12}$ to purified diets using vitamin-free casein as a protein source. Slightly better growth (mainly more fat) was obtained when five mcg of $B_{12}$ was added per pound of dry ration. Others (24) have reported improved growth of puppies when 10 mcg of $B_{12}$ was used per pound of dry ration. In view of the difficulty of demonstrating vitamin-$B_{12}$ deficiencies in dogs, this amount is certainly adequate. Diets containing significant amounts of animal proteins should provide an adequate supply of vitamin $B_{12}$ without supplementation.

## *Choline*

A choline deficiency cannot be demonstrated with some types of diets, since several factors are interrelated with the need for choline. The amounts of protein, cystine, methionine, fat, and vitamin $B_{12}$ in the diet are important factors.

Schaefer *et al.* (130) demonstrated that growing puppies on synthetic diets containing 18 per cent casein require choline in addition to the known B vitamins. When 45 mg of choline per pound of body weight per day were included in the diet, the dogs grew normally. Chaikoff and Kaplan (25) reported a peripheral fibrosis and cirrhosis of the liver in depancreatized dogs receiving insulin and small amounts of choline. Fouts (49) fed a low-casein (15 per cent) and high-fat (28 per cent) diet and also observed cirrhosis of the liver. A high-casein (41 per cent) diet prevented degeneration of the liver. Growth was still sub-optimal, however. Combined administration of 45 mg per pound of body weight per day of choline plus powdered liver extract alleviated the deficiency symptoms, but fibrosis of the liver persisted.

McKibbin *et al.* (97) fed a synthetic diet which produced fatal choline deficiency in weanling puppies in less than three weeks, but 0.7 per cent DL-methionine or 23 mg of choline chloride per pound of body weight per day corrected the deficiency. Fatty livers were evident in the choline-deficient dogs. Later reports (94, 97) confirmed these findings. Dutra (41) reported that the choline requirement of the growing dog was 11 to 23 mg per pound of body weight per day. The subject is well covered in two review articles (26, 88).

Under specific conditions of protein intake (low methionine and cystine) and fat level, growing dogs on synthetic diets require 10 to 25 mg of choline per pound of body weight per day. This amount should suffice with normal rations. Until the requirements are more definitely established, the committee recommends provision of 25 mg of choline per pound of body weight per day, especially for puppies.

## *Vitamin C*

The dog generally does not need vitamin C in the diet if the diet is otherwise adequate and the animal is under normal conditions. Under special conditions scurvy may occur; when it does, it responds dramatically to vitamin-C therapy (61).

# GENERAL CONSIDERATIONS

Proper feeding of dogs involves much more than the provision of food which supplies nutrients in adequate amounts and proper proportions. Dogs have individual food preferences and requirements, and rations which provide adequately for some animals may be refused by others or may not be well digested. This is especially true for dry rations unless they are carefully formulated to provide proper palatability, texture, and digestibility.

Some dogs accept new foods readily; others refuse a change from their customary ration unless the new food is mixed with familiar food or introduced gradually. This is good practice in introducing any new food and especially when changing from a moist or canned product to a meal-type ration.

Dogs ordinarily prefer foods which contain liberal quantities of animal proteins and fats. These products apparently add to the flavor and texture of the food and appeal to the dog's senses of taste and smell. Fats especially may be used to reduce the dryness of meals or to improve the texture of meat and meal mixtures. High levels of fat should be avoided unless special formulations are used, as they may reduce food intake, thus inducing vitamin or protein deficiencies. Levels of fat up to 10 per cent (solids basis) can ordinarily be used without concern in this connection unless the ration is already low in certain of the essential nutrients.

Sufficient food should be provided to keep the dog in good condition. The amounts suggested in Table 3 will approximate the requirements, but exact quantities depend upon the type of dog being fed. If the quantities recommended do not suffice to maintain good body condition, more food should be provided. If obesity results, the food should be restricted. Dogs getting exercise at irregular intervals (such as hunting dogs) may require extra food to compensate for the energy expenditures. Likewise, cold weather may be expected to increase the food requirements of animals in unheated quarters. The entire daily ration may be fed to adult dogs in one feeding or it may be divided into several, according to the preferences of the owner. Small puppies should be fed several times daily. Likewise, pregnant or lactating bitches may respond better to divided feedings because of the large volume of feed required.

It has been commonly believed that puppies and pregnant bitches require a higher quality of food than that needed for usual adult maintenance. Actually, their increased need for calories results in higher food intake, which usually provides adequately for the required extra protein, vitamins, and minerals if a good maintenance ration is used. Some maintenance rations, however, are apparently low in factors needed for growth and reproduction (47), and require supplementation for those functions. Puppies may not be able to digest and utilize some rations as effectively as adult dogs, especially if raw, high-fiber cereals are included. Hence, it is good practice to make certain that puppies and lactating bitches get high-quality, palatable rations.

Lactation impresses special demands upon the bitch, owing to the secretion of large amounts of protein and minerals. Unless the ration includes more than the minimal amounts of protein indicated in Table 2, supplementation with milk or meat products may be advisable. With feeds of higher protein levels, such as 25–30 per cent of the solids, protein supplementation should not be necessary. Most commercially prepared feeds provide adequately in this respect.

Dogs should have free access to fresh clean water at all times. Water is as important as food, and dogs require liberal quantities of it. Naturally, dry rations appear to increase the water intake, since, with canned or moistened

TABLE 7

MEAL-TYPE RATIONS FOR DOGS[1]

(Dry matter 91%)

| Ingredient | RATION 1 | RATION 2 |
|---|---|---|
| | % | % |
| Meat and bone meal, 55% protein | 8.00 | 15.00 |
| Fish meal, 60% protein | 5.00 | 3.00 |
| Soybean oil meal | 12.00 | — |
| Soybean grits | — | 19.00 |
| Wheat germ oil meal | 8.00 | 5.00 |
| Skim milk, dried | 4.00 | 2.50 |
| Cereal grains | 51.23 | — |
| Corn flakes | — | 26.75 |
| Wheat bran | 4.00 | — |
| Wheat flakes | — | 26.70 |
| Fat, edible | 2.00 | — |
| Bone meal, steamed | 2.00 | — |
| Brewers yeast, dried | 2.00 | 0.50 |
| Fermentation solubles, dried | 1.00 | — |
| Salt, iodized | 0.50 | 0.25 |
| Vitamin A & D feeding oil (2,250 IU of A, 400 IU of D per gm) | 0.25 | 0.50 |
| Riboflavin supplement[2] | — | 0.80 |
| Iron oxide | 0.02 | — |

[1] While these rations have been used satisfactorily with some dogs, there is no assurance that all dogs will accept them readily. See section on "General Considerations."

[2] BY-500.

food, much of the water is consumed along with the food. Feeding and watering equipment should be kept clean and in good condition.

Formulas for two meal-type rations which have been used with success in feeding dogs under experimental conditions are given in Table 7 (24, 47, 137). These particular formulas are not recommended as having special merit; they are presented merely to illustrate combinations of ingredients which have been satisfactory. Other combinations may serve equally well, and a number of commercial meals have been in use by kennels for years.

It should be remembered that palatability is an important factor in formulating rations, and that this is difficult to achieve with dry foodstuffs. Well-formulated dry feeds will be accepted by dogs and may constitute the sole ration, although many feeders prefer to mix dry meals with milk, meat, meat broth, or other moist materials. While these additions may improve palatability, they do not necessarily provide greater nutritive value than properly balanced meals.

The approximate nutrient content of various feeds and foodstuffs commonly used by kennels or manufacturers of dog food in preparing complete mixed rations are shown in Table 8, and may be used as a basis for calculating the nutrient content of specific formulas.

# TABLE 8

## PARTIAL COMPOSITION OF FEEDS COMMONLY INCLUDED IN DOG RATIONS
(all data are on an as fed basis)

| Feedstuffs | PROTEIN AND ENERGY | | | | | | INORGANIC ELEMENT | | | VITAMINS (PER LB) | | | | | | AMINO ACIDS AS % OF THE FEED | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Dry Matter | Crude Protein | Ether Extract | Fiber | Gross calories per lb | Non rumen[1] | Total Ash | Calcium | Phosphorus | Carotene | Niacin | Riboflavin | Thiamine | Alpha tocopherol | Vitamin D | Cystine | Lysine | Methionine | Tryptophan |
| | % | % | % | % | | % | % | % | % | mg | mg | mg | mg | mg | I.U. | % | % | % | % |
| ROUGHAGES | | | | | | | | | | | | | | | | | | | |
| Alfalfa meal, dehy. | 92 | 16.8 | 2.3 | 26 | 2068 | 52 | 9.5 | 1.35 | .30 | 47.4 | | | | | | | | | |
| Alfalfa meal, dehy. | 92 | 20.2 | 2.9 | 22 | | 53 | 11.8 | | | | | | | | | | | | |
| Alfalfa meal, suncured | 91 | 15.4 | 1.7 | 28 | | | 8.9 | 1.46 | .31 | | | | | | | | | | |
| Cabbage, fresh | 33 | 1.0 | .1 | | 90 | | | .03 | .02 | | | .17 | .2 | | | | | | |
| Carrots, fresh | 22 | 1.1 | .3 | | 173 | | | .03 | .03 | | | .24 | .24 | | | | | | |
| Tomato, fresh | 8 | 1 | .3 | | 96 | | | .01 | .03 | | | .18 | .2 | | | | | | |
| Tomato, pomace, dried | 92 | | 13.0 | 29 | | | 4.2 | .28 | .57 | | | 2.8 | 5.4 | | | | 1.6 | .1 | .2 |
| BASAL FEEDS | | | | | | | | | | | | | | | | | | | |
| Barley grain | 89 | 11.6 | 1.9 | 5 | 2086 | 70 | 2.7 | .08 | .42 | .2 | 26.1 | .9 | 2.3 | 2.8 | | .2 | .5 | .2 | .2 |
| Barley malt | 91 | 13.7 | 1.9 | 3 | | | 2.2 | .06 | .46 | | 25.7 | 1.3 | 1.8 | | | .2 | .5 | | .2 |
| Beet molasses | 77 | 6.7 | .2 | 0 | | | 8.2 | .16 | .03 | | 19.2 | | 1.1 | | | | | | |
| Beet pulp, dried | 91 | 9.1 | .6 | 19 | 1744 | 65 | 3.6 | .68 | .10 | .1 | 7.4 | .3 | .2 | | 275 | | .6 | 0 | .1 |
| Cane molasses | 96 | 10.3 | 1.0 | 5 | | | 7.4 | | | | | | | | | | | | |
| Corn flakes | 96 | 8.1 | .4 | | 1746 | | | .01 | .06 | | .1 | 0 | | | | | | | |
| Corn dent grain | 86 | 9.0 | 3.9 | 2 | 2001 | | 1.3 | .03 | .27 | 1.7 | 9.7 | .6 | 1.8 | | | | | | |
| Corn meal | 92 | 10.3 | 3.5 | 2 | | | 1.4 | | | | | | | | | | | | |
| Corn hominy feed | 91 | 10.7 | 6.5 | 5 | 1939 | | 2.5 | .05 | .53 | 4.2 | 23.2 | .9 | 3.6 | | | | | | |
| Oatmeal feed grade | 91 | 16.1 | 6.3 | 3 | | | 2.2 | .07 | .45 | | 5.8 | .8 | 3.2 | | | | .6 | .2 | .2 |

[1] Per cent of gross calories utilizable by monogastric animals.

# TABLE 8 (*Continued*)

| Feedstuffs | Protein and Energy: Dry Matter | Crude Protein | Ether Extract | Fiber | Gross calories per lb | Non rumen[1] | Inorganic Element: Total Ash | Calcium | Phosphorus | Vitamins (per lb): Carotene | Niacin | Riboflavin | Thiamine | Alpha tocopherol | Vitamin D | Amino Acids as % of the Feed: Cystine | Lysine | Methionine | Tryptophan |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | % | % | % | % | | % | % | % | % | mg | mg | mg | mg | mg | I.U. | % | % | % | % |
| Oats grain | 89 | 11.8 | 4.5 | 11 | 2138 | 65 | 3.6 | .10 | .35 | 0 | 7.2 | .7 | 2.8 | | | .2 | .4 | .2 | .2 |
| Rice, puffed | 96 | 5.9 | .6 | | 1765 | | | .02 | .12 | | | .36 | .36 | | | | | | |
| Rice bran | 91 | 13.5 | 15.1 | 11 | | 74 | 10.9 | .06 | 1.82 | | 137.8 | 1.2 | 10.2 | | | .1 | .5 | | .1 |
| Rice grain | 89 | 8.2 | 1.2 | 2 | 1814 | | 1.6 | .04 | .23 | | 16.2 | .3 | 1.2 | 3.2 | | .1 | .3 | .2 | .1 |
| Rice polished | 89 | 7.3 | .4 | 0 | 1840 | 86 | .6 | .03 | .14 | | 7.2 | .3 | .3 | 1.8 | | .1 | .3 | .3 | .1 |
| Rice, brown grain | 88 | 7.5 | 1.7 | | 1648 | | | .04 | .30 | | | .23 | 1.45 | | | | | | |
| Sorghum, kafir grain | 90 | 11.8 | 2.9 | 2 | | 80 | 1.7 | .04 | .33 | .2 | 16.6 | .6 | 1.7 | | | | .3 | .2 | .2 |
| Sorghum, milo grain | 89 | 11.0 | 2.8 | 2 | 1948 | 78 | 1.9 | .04 | .29 | .2 | 19.4 | .5 | 1.8 | | | .2 | .3 | .1 | .1 |
| Wheat bread dried | 90 | 9.9 | 2.0 | | 1544 | | | .04 | .34 | | | .56 | 1.63 | | | | | | |
| Wheat, flaked | 96 | 10.8 | 1.6 | | 1612 | | | .05 | .33 | | | 1.82 | 1.36 | | | | | | |
| Wheat bran | 89 | 16.0 | 4.1 | 10 | 1842 | 57 | 6.1 | .14 | 1.17 | 1.2 | 95.1 | 1.4 | 3.6 | 449.0 | | .3 | .6 | .1 | .4 |
| Wheatbran flakes | | | | | | | | | | | | | | | | | | | |
| Wheat middlings | 89 | 18.0 | 3.6 | 2 | | 73 | 2.5 | .08 | .52 | | 23.9 | .7 | 8.6 | 26.2 | | | .6 | .1 | .2 |
| Wheat middlings, standard | 90 | 17.2 | 4.6 | 8 | | 64 | 4.4 | .15 | .91 | 1.4 | 44.8 | .9 | 5.8 | | | .2 | .7 | .2 | .2 |
| Wheat, northern spring | 90 | | | | 2157 | | | .06 | .42 | 0 | 27.3 | .5 | 2.4 | | | | | | |
| Wheat, red hard, winter | 89 | | | | 1814 | | | .05 | .40 | | 23.1 | .4 | 2.8 | | | | | | |
| Wheat, soft, Pacific Coast | 89 | | | | 1796 | | | .09 | .29 | | 26.1 | | 2.4 | | | .2 | .8 | | .3 |
| PROTEIN SUPPLEMENTS | | | | | | | | | | | | | | | | | | | |
| PLANT 16–30% PROT. | | | | | | | | | | | | | | | | | | | |
| Corn dist. grains with solubles, dried | 92 | 27.2 | 9.3 | 9 | 2058 | | 4.3 | .17 | .68 | 1.7 | 30.4 | 3.9 | 1.3 | | 250.0 | | .7 | .5 | .1 |
| Corn dist. solubles, dried | 93 | 26.9 | 9.1 | 4 | | 75 | 8.0 | .35 | 1.37 | .3 | 52.4 | 7.7 | 3.1 | | | | .9 | .6 | .2 |

| | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Corn germ meal | 93 | 20.2 | 7.6 | 9 | 2141 | | 2.9 | .05 | .51 | | 18.5 | 1.4 | 9.0 | | | | |
| Corn gluten meal | 90 | 26.0 | 3.8 | 8 | | | 4.6 | .10 | .74 | | | | | | | | |
| Wheat germ meal | 90 | 26.2 | 10.9 | 3 | 1912 | | 4.3 | .07 | 1.04 | | | | | | | | |
| Yeast brewers, dried | 95 | 24.0 | .6 | 7 | | | 14.0 | | | | 116.0 | 12.3 | 34.8 | | .7 | .4 | .2 |
| PLANT 30% AND OVER | | | | | | | | | | | | | | | | | |
| Cottonseed oil meal, sol. | 91 | 41.6 | 1.6 | 11 | 1920 | | 6.5 | .15 | 1.10 | | 20.7 | 2.1 | 3.7 | | 1.6 | .6 | .5 |
| Flaxseed oil meal, exp. | 91 | 35.3 | 5.2 | 9 | 1928 | 77 | 5.6 | .44 | .89 | .1 | 16.2 | 1.6 | 2.3 | | | .7 | |
| Peanut oil meal, exp. | 92 | 45.8 | 5.9 | 11 | | | 5.7 | .17 | .57 | .1 | 76.8 | 2.4 | 3.3 | | 1.3 | .6 | .5 |
| Peanut oil meal, sol. | 92 | 47.4 | 1.2 | 13 | | | 4.5 | .20 | .65 | | 77.3 | 5.0 | 3.3 | | 2.3 | .4 | .5 |
| Soybean oil meal, sol. | 89 | 45.8 | .9 | 6 | 1908 | 75 | 5.8 | .32 | .67 | .1 | 12.2 | 1.5 | 3.0 | | 2.9 | .6 | .6 |
| Soybean oil meal, sol. | | 44.0 | | | | | | | | | | | | | | | |
| Soybean oil meal, sol. | | 41.0 | | | | | | | | | | | | | | | |
| ANIMAL, UNSPECIFIED | | | | | | | | | | | | | | | | | |
| Blood meal | 91 | 79.9 | 1.6 | 1 | 2368 | 61 | 5.6 | .28 | .22 | | 14.3 | .7 | | 1.4 | 6.9 | .9 | 1.1 |
| Intestines | 31 | 11.0 | 19.0 | | 998 | | | .01 | .11 | | | | | | | | |
| Meat meal | 94 | 53.4 | 9.9 | 2 | 1443 | | | | | | | | | | | | |
| Meat and bone | 94 | 50.6 | 9.5 | 2 | | 79 | | | | | | | | | | | |
| Spleen | 23 | 18.1 | 3.0 | | 449 | | 1.4 | | | | | | | | | | |
| Tankage | 92 | 59.8 | 8.1 | 2 | | | 21.4 | 5.94 | 3.17 | | 17.8 | 1.1 | | | 4.0 | .8 | .7 |
| Tripe | 21 | 19.1 | 2.0 | | 452 | | | | | | 1.6 | .15 | .01 | | | | |
| Udders | 35 | 15.4 | 18.7 | | 1053 | | | .07 | .16 | | | | | | | | |
| CATTLE | | | | | | | | | | | | | | | | | |
| Brain, fresh | 22 | 10.5 | 9.0 | | 577 | | 1.4 | .1 | .38 | | | | | | | | |
| Buttermilk cond. | 29 | 10.7 | 2.5 | 0 | | | 3.4 | .44 | .26 | | | 6.5 | | | | | |
| Buttermilk, dried | 93 | 32.0 | 5.8 | 0 | | 77 | 9.6 | 1.34 | .94 | | 3.9 | 14.1 | 1.6 | | 2.4 | .7 | .5 |
| Heart, fresh | 22 | 16.9 | 4.0 | | 490 | | 1.1 | .01 | .20 | | | | | | | | |
| Kidney, fresh | 25 | 15.0 | 8.0 | | 640 | | 1.1 | .01 | .22 | | | | | | | | |
| Liver, fresh | 30 | 19.7 | 3.0 | | 617 | | 1.4 | .01 | .36 | | | | | | | | |
| Lips | 37 | 17.4 | 9.4 | | | | .9 | | | | | | | | | | |
| Liver meal | 93 | 66.5 | 15.1 | 1 | | | | | | | | | | | | | |
| Lung, fresh | 21 | 18.3 | 2.0 | | 404 | | 1.0 | | | | | | | | | | |
| Pancreas, fresh | 40 | 13.5 | 25.0 | | 1267 | | 1.2 | | | | | | | | | | |
| Round, fresh | 31 | 19.5 | 11.0 | | 826 | | 1.0 | .01 | .18 | | | | | | | | |
| Skim milk, dried | 92 | 47.3 | 1.1 | 1 | | | 30.4 | 11.72 | 4.53 | | | | | | | | |
| Spleen, fresh | 23 | 18.1 | 3.0 | | 449 | | 1.4 | | | | | | | | | | |

# TABLE 8 (*Continued*)

| | PROTEIN AND ENERGY | | | | | | INORGANIC ELEMENT | | | VITAMINS (PER LB) | | | | | | AMINO ACIDS AS % OF THE FEED | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Feedstuffs | Dry Matter | Crude Protein | Ether Extract | Fiber | Gross calories per lb | Non rumen[1] | Total Ash | Calcium | Phosphorus | Carotene | Niacin | Riboflavin | Thiamine | Alpha tocopherol | Vitamin D | Cystine | Lysine | Methionine | Tryptophan |
| | % | % | % | % | | % | % | % | % | mg | mg | mg | mg | mg | I.U. | % | % | % | % |
| Thymus, fresh | 46 | 11.8 | 33.0 | | 1562 | | 1.1 | .01 | .6 | | | | | | | | | | |
| Tongue, fresh | 32 | 16.4 | 15.0 | | 940 | | 9 | .01 | .19 | | | | | | | | | | |
| Veal Leg, Fresh | 32 | 19.1 | 12.0 | | 844 | | 1.0 | .01 | .21 | | | | | | | | | | |
| HORSE | | | | | | | | | | | | | | | | | | | |
| Meat | 24 | 18.1 | 4.1 | | 540 | | .9 | .01 | .18 | | | | | | | | | | |
| SHEEP | | | | | | | | | | | | | | | | | | | |
| Heart, fresh | 31 | 16.9 | 12.6 | | | | .9 | | | | | | | | | | | | |
| Kidney, fresh | 21 | 16.5 | 3.2 | | | | 1.3 | | | | | | | | | | | | |
| Liver, fresh | 39 | 23.1 | 9.0 | | | | 1.7 | | | | | | | | | | | | |
| SWINE | | | | | | | | | | | | | | | | | | | |
| Heart, fresh | 24 | 17.1 | 6.3 | | | | 1.0 | | | | | | | | | | | | |
| Kidney, fresh | 22 | 15.5 | 4.8 | | | | 1.2 | | | | | | | | | | | | |
| Liver, fresh | 27 | 19.8 | 5.3 | | | | — | | | | | | | | | | | | |
| Pancreas, fresh | 36 | 15.8 | 18.4 | | | | | | | | | | | | | | | | |
| Spleen, fresh | 21 | 17.3 | 1.9 | | | | | | | | | | | | | | | | |
| AVIAN, UNSPECIFIED BY-PRODUCT | | | | | | | | | | | | | | | | | | | |
| Eggs, without shell | 26 | 12.8 | 11.5 | | | 737 | | .05 | .21 | | | .29 | .1 | | | | | | |
| Eggs, with shell | 34 | 11.4 | 10.2 | | | 685 | | .06 | .19 | | | .26 | .09 | | | | | | |
| Feet | | | | | | | | | | | | | | | | | | | |
| Head | | | | | | | | | | | | | | | | | | | |
| Viscera | | | | | | | | | | | | | | | | | | | |

| | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| MARINE FISH, UNSPECIFIED | | | | | | | | | | | | | | | | |
| Fish solubles, cond. | 51 | 31.4 | 6.5 | 1 | | 10.0 | .61 | .70 | .6 | 76.7 | 6.6 | 2.5 | 1.7 | 2.7 | 1.0 | .8 |
| Alewife | | | | | | | | | | | | | | | | |
| Carp | | | | | | | | | | | | | | | | |
| Catfish | | | | | | | | | | | | | | | | |
| Cod | | | | | | | | | | | | | | | | |
| Flounder | | | | | | | | | | | | | | | | |
| Haddock | 61 | 7.8 | 0 | | 170 | | .01 | .1 | | | .04 | .02 | | | | |
| Herring meal, dried | 92 | 70.6 | 7.5 | 0 | | 10.8 | 2.94 | 2.2 | | 40.4 | 4.1 | | 1.6 | 7.3 | 2.0 | .9 |
| Mackerel | 61 | 10.1 | 6.0 | | 457 | | — | .13 | | | .19 | .08 | | | | |
| Menhaden meal | 92 | 61.3 | 7.7 | 1 | | 19.6 | 5.49 | 2.81 | | 25.4 | 2.2 | .3 | | 5.3 | 1.8 | .6 |
| Redfish meal | 94 | 57.0 | 8.4 | 1 | | 25.5 | 7.73 | 3.93 | | | 3.2 | | | 6.5 | 1.8 | .6 |
| Redfish, rose | | | | | | | | | | | | | | | | |
| Salmon | 93 | 58.0 | 9.6 | 0 | | 16.7 | 5.44 | 3.26 | | 11.3 | 2.6 | .4 | .7 | 7.6 | 1.6 | .5 |
| Sardine meal | 93 | 65.5 | 4.3 | 1 | | 15.7 | 4.90 | 2.77 | | 28.2 | 2.7 | .2 | .8 | 5.9 | 2.0 | .5 |
| Sheepshead | | | | | | | | | | | | | | | | |
| Smelt | | | | | | | | | | | | | | | | |
| Whitefish | | | | | | | | | | | | | | | | |
| Whitefish meal | 92 | 63.2 | 4.4 | 1 | | 21.7 | 7.87 | 3.61 | | 31.7 | 4.1 | .8 | | | | |
| Whiting | | | | | | | | | | | | | | | | |

## REFERENCES CITED


1. Aaron, A. and J. S. Schad. Nitrogen balance studies with dogs on casein or methionine supplemented casein. J. Nutrition *53:* 265. 1954.
2. Afonsky, D. Folic acid deficiency in the dog. Science *120:* 803. 1954.
3. Allison, J. B., J. A. Anderson, and R. D. Seeley. The determination of the nitrogen balance index in normal and hypoproteinemic dogs. Ann. N. Y. Acad. Sci. *47:* 245. 1945.
4. Allison, J. B., R. D. Seeley, J. H. Brown, and J. A. Anderson. The evaluation of proteins in hypoproteinemic dogs. J. Nutrition *31:* 237. 1946.
5. Allison, J. B., J. A. Anderson, and R. D. Seeley. Some effects of methionine in the utilization of nitrogen in the adult dog. J. Nutrition *33:* 361. 1947.
6. Allison, J. B. Nitrogen balance and the nutritive value of proteins. J. Am. Med. Assoc. *164:* 283. 1957.
7. Allison, J. B. Balance and imbalance of amino acids both in regard to human and animal nutrition. Voeding *19:* 119. 1958.
8. Allison, J. B. Amino acid requirements. Feedstuffs. Dec. 13, 1958.
9. Anderson, H. D., C. A. Elvehjem, and J. E. Gonce, Jr. Vitamin E deficiency in dogs. Proc. Soc. Exptl. Biol. Med. *42:* 750. 1939.
10. Anderson, H. D., C. A. Elvehjem, and J. E. Gonce, Jr. Comparison of the nutritive values of raw, pasteurized and evaporated milks for the dog. J. Nutrition *20:* 433. 1940.
11. Arnold, A. and C. A. Elvehjem. Nutritional requirements of dogs. J. Am. Vet. Med. Assoc. *95:* 187. 1939.
12. Arnold, A. and C. A. Elvehjem. Is running fits a deficiency disease? J. Am. Vet. Med. Assoc. *95:* 303. 1939.
13. Arnold, A. and C. A. Elvehjem. Influence of the composition of the diet on the thiamine requirement of dogs. Am. J. Physiol. *126:* 289. 1939.
14. Arnrich, L., E. M. Lewis, and A. F. Morgan. Growth of Dogs on Purified Diet Plus Aureomycin and/or Vitamin $B_{12}$. Proc. Soc. Exptl. Biol. and Med. *80:* 401. 1952.
15. Axelrod, A. E., M. A. Lipton, and C. A. Elvehjem. The production of uncomplicated riboflavin deficiency in the dog. Am. J. Physiol. *128:* 703. 1940.
16. Axelrod, A. E., M. A. Lipton, and C. A. Elvehjem. Riboflavin deficiency in the dog. Am. J. Physiol. *133:* 555. 1941.
17. Axelrod, H. E., M. G. Callberg, and A. F. Morgan. Carbohydrate metabolism in riboflavin deficient dogs. Am. J. Physiol. *165:* 604. 1951.
18. Axelrod, H. E., A. F. Morgan, and S. Lepkovsky. The fate of tryptophane in pyridoxine deficient and normal dogs. J. Biol. Chem. *160:* 155. 1945.
19. Birch, T. W. The requirements of the dog and the rat for nicotinic acid. J. Nutrition *17:* 281. 1939.
20. Birch, T. W., P. Gyorgy, and L. J. Harris. The vitamin $B_2$ complex. Differentiation of the antiblacktongue and the P-P factors from lactoflavin and vitamin $B_6$ (so-called rat pellagra factor). Parts I–VI. Biochem. J. *29:* 2830. 1935.
21. Borson, H. J. and S. R. Mettier. Relief of hypochromic anemia in dogs with synthetic vitamin $B_6$. Influence of filtrate factors. Proc. Soc. Exptl. Biol. Med. *43:* 429. 1940.
22. Bradfield, D. and M. C. Smith. The ability of the dog to utilize vitamin A from plant and animal sources. Am. J. Physiol. *124:* 168. 1938.
23. Brody, S., R. C. Proctor, and U. S. Ashworth. Growth and development. XXXIV. Basal metabolism, endogenous nitrogen, creatinine and neutral sulphur excretions as functions of body weight. Univ. of Missouri College of Agriculture. Res. Bull. 220. 1934.

24. Campbell, J. E. and P. H. Phillips. Some problems on feeding fat to dogs. The Southwestern Veterinarian *6:* 173. 1953.
25. Chaikoff, I. L. and A. Kaplan. Survival of the completely depancreatized dog. J. Nutrition *14:* 459. 1937.
26. Choline deficiency studies in dogs. Nutrition Revs. *3:* 124. 1945.
27. Committee on Animal Nutrition. Recommended nutrient allowances for domestic animals IV. Recommended nutrient allowances for horses. National Research Council. Washington, D.C. 1949.
28. Committee on Animal Nutrition. Recommended nutrient allowances for domestic animals V. Recommended nutrient allowances for sheep. National Research Council. Publ. 504. Washington, D.C. 1957.
29. Committee on Animal Nutrition. Nutrient requirements of domestic animals III. Nutrient requirements of dairy cattle. National Research Council. Publ. 464. Washington, D.C. 1958.
30. Committee on Animal Nutrition. Nutrient requirements of domestic animals I. Nutrient requirements of poultry. National Research Council. Publ. 827. Washington, D.C. 1960.
31. Committee on Animal Nutrition. Nutrient requirements of domestic animals II. Nutrient requirements of swine. National Research Council. Publ. 648. Washington, D.C. 1959.
32. Cowgill, G. R. A contribution to the study of the relation between vitamin B and the nutrition of the dog. Am. J. Physiol. *57:* 420. 1921.
33. Cowgill, G. R. The energy factor in relation to food intake: Experiments on the dog. Am. J. Physiol. *85:* 45. 1928.
34. Cowgill, G. R. The vitamin $B_1$ requirement of man. New Haven, Conn.: Yale University Press. 1934.
35. Grimm, P. D. and D. M. Short. Vitamin A deficiency in the dog. Am. J. Physiol. *118:* 477. 1937.
36. Dann, W. J. and P. Handler. Nicotinic acid and coenzyme content of the tissues of normal and blacktongue dogs. J. Nutrition *22:* 409. 1941.
37. Dann, W. J., H. I. Kohn, and P. Handler. The effect of pyrazine acids and quinolinic acid on the V-factor content of human blood and upon canine blacktongue. J. Nutrition *20:* 477. 1940.
38. Drill, V. A. The caloric intake and weight balance of hyperthyroid dogs in relation to vitamin $B_1$ and yeast. Am. J. Physiol. *132:* 629. 1941.
39. Drill, V. A. and H. W. Hays. The relation of the liver function, pulse rate and temperature of hyperthyroid dogs to vitamin $B_1$ and yeast. Am. J. Physiol. *136:* 762. 1942.
40. Drill, V. A. and C. B. Shaffer. Effect of vitamin $B_1$ and yeast on caloric intake and weight balance of hyperthyroid dogs. Endocrinology *31:* 567. 1942.
41. Dutra, F. R. and J. M. McKibbin. The pathology of experimental choline deficiency in dogs. J. Lab. Clin. Med. *30:* 301. 1945.
42. Earle, I. P. Nutrition requirements of the dog. U.S. Dept. of Agriculture Yearbook. Washington, D.C.: U.S. Government Printing Office, p. 849. 1939.
43. Efremov, V. V., A. I. Makarychev, and A. N. Tikhomirova. Effects of niacin avitaminosis on conditioned reflexes in dogs. Voprosy Pitaniya 13: 10, 1954. Chem. Abst., *49:* 11800c. (1955).
44. Elvehjem, C. A., J. E. Gonce, Jr., and G. W. Newell. The effect of vitamin E on reproduction in dogs on milk diets. J. Pediat. *24:* 436. 1944.
45. Elvehjem, C. A., E. B. Hart, and W. C. Sherman. The availability of iron from different sources for hemoglobin formation. J. Biol. Chem. *103:* 61. 1933.

46. Elvehjem, C. A., E. B. Hart, and W. C. Sherman. Limitations of cereal-milk diets for hemoglobin formation. J. Pediat. *4:* 65. 1934.
47. Federal Specification N-F-170, May 4, 1951. Feed, dry, for dogs. Washington, D.C.: U.S. Government Printing Office. 1951.
48. Fleischman Laboratories. Vitamin D. Digest *2:* 7. 1940.
49. Fouts, P. J. Vitamin B complex studies in dogs: Production of cirrhosis of liver. J. Nutrition *25:* 217. 1943.
50. Fouts, P. J., O. M. Helmer, S. Lepkovsky, and T. H. Jukes. Production of microcytic hypochromic anemia in puppies on synthetic diet deficient in rat anti-dermatitis factor. J. Nutrition *16:* 197. 1938.
51. Fouts, P. J., S. Lepkovsky, O. H. Kelmer, and T. H. Jukes. Cure of microcytic hypochromic anemia in dogs with crystalline "Factor I." Proc. Soc. Exptl. Biol. Med. *40:* 4. 1939.
52. Frohring, W. O. Vitamin A requirements of growing puppies. Proc. Soc. Exptl. Biol. Med. *33:* 280. 1935.
53. Frohring, W. O. Vitamins and distemper. Vet. Med. *32:* 76; 190. 1937.
54. Frost, D. V. and C. A. Elvehjem. The role of iron, copper, and cobalt in hemoglobin production in dogs on a milk diet. J. Biol. Chem. *128:* XXXI. 1939.
55. Frost, D. V., C. A. Elvehjem, and E. B. Hart. Iron utilization in dogs on milk diets. J. Nutrition *19:* 311. 1940.
56. Gantt, W. H., B. F. Chow, and M. Simonson. Effect of pyridoxine and pantothenic acid deficiency on conditional reflexes. Am. J. Clin. Nutr., *7:* 411. 1959.
57. Gershoff, S. N., M. A. Legg, and D. M. Hegsted. Adaptation to different calcium intakes in dogs. J. Nutrition *64:* 303. 1958.
58. Gessert, C. T. and P. H. Phillips. Protein in the nutrition of the growing dog. J. Nutrition *58:* 415. 1956.
59. Gillis, M. B. Potassium requirement of the chick. J. Nutrition *36:* 351. 1948.
60. Goldberger, J. and G. A. Wheeler. Experimental pellagra in white male convicts. Arch. Internal Med. *25:* 451. 1920.
61. Garlick, N. L. True scurvy in the dog. Am. Vet. Med. Assoc. *109:* 70–71. July 1946.
62. Hale, Maurice W. Personal communication.
63. Handler, P. Use of highly purified rations in the study of nicotinic acid deficiency. Proc. Soc. Exptl. Biol. Med. *52:* 263. 1943.
64. Hansen, A. E., H. F. Wiese, and O. Beck. Susceptibility of infection manifested by dogs on a low fat diet. Federation Proc. *7:* 289. 1948.
65. Hansen, A. E. and H. F. Wiese. Studies with dogs maintained on diets low in fat. Proc. Soc. Exptl. Biol. Med. *52:* 205. 1943.
66. Hansen, A. E. and H. F. Wiese. Fat in the diet in relation to nutrition of the dog. I. Characteristic appearance and gross changes of animals fed diets with and without fat. Texas Reports Biol. and Med. *9:* 491. 1951.
67. Hegsted, D. M., V. Kent, A. G. Tsongas, and F. J. Stare. Comparison of the nutritive value of the proteins in mixed diets for dogs, rats, and human beings. J. Lab. Clin. Med. *32:* 403. 1947.
68. Heiman, V. The protein requirements of growing puppies. J. Am. Vet. Med. Assoc. *111:* 304. 1947.
69. Hendricks, J. B., A. F. Morgan, and R. M. Freytag. Chronic moderate hypervitaminosis D in young dogs. Am. J. Physiol. *149:* 319. 1947.
70. Hoff-Jorgensen, E. The influence of phytic acid on the absorption of calcium and phosphorus. Biochem. J. *40:* 189. 1946.
71. Ivy, A. C. Starch digestion in the dog. Vet. Med. *31:* 145. 1936.

72. Ivy, A. C., C. R. Schmidt, and J. Beazell. Starch digestion in the dog. North Am. Vet. *17:* 44. 1936.
73. James, W. T. and C. M. McCay. A study of feed intake, activity, and digestive efficiency in different type dogs. Am. J. Vet. Research *11:* 412. 1950.
74. Jenkins, K. J. and P. H. Phillips. The mineral requirements of the dog. I. Phosphorus requirement and availability. J. Nutrition *70:* 235. 1960.
75. Jenkins, K. J. and P. H. Phillips. The mineral requirements of the dog. II. The relation of calcium, phosphorus, and fat levels to minimum calcium and phosphorus requirements. J. Nutrition *70:* 241. 1960.
76. Kade, C. F., J. H. Phillips, and W. A. Phillips. The determination of the minimum nitrogen requirement of the adult dog for maintenance of nitrogen balance. J. Nutrition *36:* 109. 1948.
77. Karr, W. G. Some effects of water-soluble vitamin upon nutrition. J. Biol. Chem. *44:* 255. 1920.
78. Katz, L. N., S. Rodbard, and J. Meyer. Blood pressure responses of dogs to vitamin A and vitamin $D_2$. Am. J. Physiol. *140:* 226. 1943.
79. Keane, K. W., F. I. Nakamura, and M. L. Morris. Vitamin A plasma levels of dogs. North Am. Vet. *28:* 587. 1947.
80. Koehn, C. J. Practical dog feeding. Alabama Agr. Expt. Sta. Bull. *251:* 3. 1942.
81. Kohn, H. E., J. R. Klein, and W. J. Dann. The V-factor content and oxygen consumption of tissues of the normal and blacktongue dog. Biochem. J. *33:* 1432. 1939.
82. Kozelka, F. L., E. B. Hart, and G. Bohstedt. Growth, reproduction, and lactation in the absence of the parathyroid glands. J. Biol. Chem. *100:* 715. 1933.
83. Kraybill, H. R. and P. B. Curtis. Commercial feeding stuffs. Purdue Univ. Agr. Expt. Sta. Circ. *236:* 6. 1938.
84. Krehl, W. A., L. J. Teply, and C. A. Elvehjem. Effect of corn grits on nicotinic acid requirements of the dog. Proc. Soc. Exptl. Biol. Med. *58:* 334. 1945.
85. Lavers, M. K., P. A. Stefanik, and C. F. Code. Effect of thiamine deficiency on canine gastric secretion of acid. Am. J. Physiol. *197:* 2, 253. 1959.
86. Layne, J. A. and J. B. Carey. The effect of a blacktongue-producing diet upon the endoscopic appearance of the gastric mucosa in the dog. Gastroenterology *2:* 133. 1944.
87. Linton, R. G. Canine nutrition. 12th Internat'l. Vet. Congress, New York *3:* 388. 1935.
88. Liver function and experimental choline deficiency in dogs. Nutrition Revs. *3:* 261. 1945.
89. Maass, A. R., L. Michaud, and H. Spector. Relation of thiamine to blood regeneration. Arch. Biochem. *4:* 105. 1944.
90. McCance, R. A. Medical problems in mineral metabolism. 3. Experimental human salt deficiency. Lancet *230:* 765. 1936.
91. McCance, R. A. and E. M. Widdowson. Mineral metabolism. Annual Review Biochem. XIII, 315. 1944.
92. McCay, C. M. Nutrition of the dog. Ithaca, N.Y.: Comstock Publishing Co. 1949.
93. McKibbin, J. M., S. Black, and C. A. Elvehjem. The essential nature of pantothenic acid and another alkali-labile factor in the nutrition of the dog. Am. J. Physiol. *130:* 365. 1940.
94. McKibbin, J. M., R. M. Ferry, S. Thayer, E. G. Patterson, and F. J. Stare. Studies on choline deficiency in dogs. J. Lab. Clin. Med. *30:* 422. 1945.

95. McKibbin, J. M., R. J. Madden, S. Black, and C. A. Elvehjem. The importance of vitamin $B_6$ and factor W in the nutrition of dogs. Am. J. Physiol. *128:* 102. 1939.
96. McKibbin, J. M., A. E. Schaefer, D. V. Frost, and C. A. Elvehjem. Studies on anemia in dogs due to pyridoxine deficiency. J. Biol. Chem. *142:* 77. 1942.
97. McKibbin, J. M., S. Thayer, and F. J. Stare. Choline deficiency studies in dogs. J. Lab. Clin. Med. *29:* 1109. 1944.
98. Margolis, G., L. H. Margolis, and S. G. Smith. Cure of experimental canine blacktongue with optimal and minimal doses of nicotinic acid. J. Nutrition *16:* 541. 1938.
99. Margolis, L. H., G. Margolis, and S. G. Smith. Secondary deficiency of vitamin $B_1$ and riboflavin in the blacktongue-producing diet. J. Nutrition *17:* 63. 1939.
100. Marine, D. and C. H. Lenhart. Effect of the administration or the withholding of iodine-containing compounds in normal colloid on actively hyperplastic (parenchymatous) thyroids of dogs. Arch. Internal. Med. *4:* 233. 1909.
101. Mellanby, E. Accessory food factors (vitamins) in the feeding of infants. Lancet *1:* 856. 1920.
102. Mellanby, E. The experimental production of deafness in young animals. J. Physiol. *94:* 380. 1938.
103. Michaud, L. and C. A. Elvehjem. The nutritional requirements of the dog. North Am. Vet. *25:* 657. 1944.
104. Mitchell, H. H. Some species and age difference in amino acid requirements of mammals. In Protein and Amino Acid Requirements of Mammals. A. A. Albanese. N.Y., Academic Press, Inc. 1950.
105. Morgan, A. F. The effects of acid, neutral, and basic diets on the calcium and phosphorus metabolism of dogs. Univ. of California Publications in Physiology *8:* 61. 1934.
106. Morgan, A. F. The food needs of dogs. Vet. J. *91:* 204. 1935.
107. Morgan, A. F., H. E. Axelrod, and M. Groody. The effect of a single massive dose of vitamin $D_2$ on young dogs. Am. J. Physiol. *149:* 319. 1947.
108. Morgan, A. F. and L. S. Bentley. The excretion of vitamin A in dog urine. Federation Proc. *2:* 67. 1943.
109. Morgan, A. F. and N. Shimotori. The absorption and retention by dogs of single massive doses of various forms of vitamin D. J. Biol. Chem. *147:* 189. 1943.
110. Neumier, J. F. and L. R. Dugan, Sr. The use of antioxidants in dry dog food. Food Technology *7:* 189. 1953.
111. Ontko, J. A., R. E. Wuthier, and P. H. Phillips. The effect of increased dietary fat upon the protein requirement of the growing dog. J. Nutrition *62:* 163. 1957.
112. Ontko, J. A. and P. H. Phillips. Reproduction and lactation studies with bitches fed semi-purified diets. J. Nutrition *65:* 211. 1958.
113. Petrovaskaja, N. I., Conditioned elementary salivation reflexes in puppies, normal and deprived of vitamin $B_1$. Nutr. Abs. and Rev. *29:* 1. 1959. No. 370.
114. Phillips, P. H. Unpublished data.
115. Phillips, P. H. and E. B. Hart. The effect of organic dietary constituents upon chronic fluorine toxicosis in the rat. J. Biol. Chem. *109:* 657. 1935.
116. Potter, R. L., A. E. Axelrod, and C. A. Elvehjem. Riboflavin requirement of the dog. J. Nutrition *24:* 449. 1942.

117. Potter, V. R., C. A. Elvehjem, and E. B. Hart. Anemia studies with dogs. J. Biol. Chem. *126:* 155. 1938.
118. Quick, A. J., C. V. Hussey, and G. E. Collentine, Jr. Vitamin K requirements of adult dogs and the influence of bile on its absorption from the intestine. Am. J. Physiol. *176:* 239. 1954.
119. Reber, Elwood F., O. P. Malhotra, Julius P. Kreier, Horace W. Norton, and Paul D. Beamer. The effects of feeding irradiated flour to dogs. I. Growth. Toxicology and Applied Pharmacology I: 55. 1959.
120. Reber, Elwood F. Personal Communication.
121. Robinson, H. E. Unpublished data.
122. Rose, W. C. and E. E. Rice. The significance of the amino acids in canine nutrition. Science *90:* 186. 1939.
123. Rosenbloom, B. B. and J. W. Patton. Starch digestion in the dog. J. Am. Vet. Med. Assoc. *74:* 768. 1929.
124. Rosenbloom, B. B. and J. W. Patton. The digestion and absorption of raw starch in dogs. Am. J. Physiol. *100:* 178. 1932.
125. Ruegamer, W. R., C. A. Elvehjem, and E. B. Hart. Potassium deficiency in the dog. Proc. Soc. Exptl. Biol. Med. *61:* 234. 1946.
126. Ruegamer, W. R., L. Michaud, E. B. Hart, and C. A. Elvehjem. The use of the dog for studies on iron availability. J. Nutrition *32:* 101. 1946.
127. Russell, W. C. and M. L. Morris. Vitamin A deficiency in the dog. 1. Experimental production of the vitamin A deficient condition. J. Am. Vet. Med. Assoc. *95:* 316. 1939.
128. Sarett, H. P. Studies of nicotinic acid metabolism. II. The fate of nicotinic acid in normal and blacktongue dogs. J. Nutrition *23:* 35. 1942.
129. Schachter, D. and S. M. Rosen. Active transport of $Ca^{45}$ by the small intestine and its dependence on vitamin $D_1$. Am. J. Physiol. *196:* 357. 1959.
130. Schaefer, A. E., J. M. McKibbin, and C. A. Elvehjem. Importance of choline in synthetic rations for dogs. Proc. Soc. Exptl. Biol. Med. *47:* 365. 1941.
131. Schaefer, A. E., J. M. McKibbin, and C. A. Elvehjem. Pantothenic acid deficiency studies in dogs. J. Biol. Chem. *143:* 321. 1942.
132. Schaefer, A. E., J. M. McKibbin, and C. A. Elvehjem. Nicotinic acid deficiency studies in dogs. J. Biol. Chem. *144:* 679. 1942.
133. Schaefer, A. E. The nutritional requirements of the dogs. Feedstuffs *27:* 6, 64. 1955.
134. Scudi, J. V. and M. Hamlin. The effect of pantothenic acid deficiency on the blood lipoids of the dog. J. Nutrition *24:* 273. 1942.
135. Sebrell, W. H., R. H. Onstott, H. F. Fraser, and F. S. Daft. Nicotinic acid in the prevention of the blacktongue of dogs. J. Nutrition *16:* 355. 1938.
136. Sherman, W. C., C. A. Elvehjem, and E. B. Hart. Further studies on the availability of iron in biological materials. J. Biol. Chem. *107:* 383. 1934.
137. Siedler, A. J. and B. S. Schweigert. Effect of the level of fat in the diet on the growth performance of dogs. J. Nutrition *48:* 81. 1952.
138. Siedler, A. J. and B. S. Schweigert. Effect of the level of animal fat in the diet on the maintenance, reproduction, and lactation performance of dogs. J. Nutrition *53:* 187. 1954.
139. Silber, R. H. Studies of pantothenic acid deficiency in dogs. J. Nutrition *27:* 425. 1944.
140. Smith, S. G., R. Curry, and H. Hawfield. Nicotinic acid storage in the dog at different dose levels of the vitamin. J. Nutrition *25:* 341. 1943.

141. Spector, H., A. R. Maass, L. Michaud, C. A. Elvehjem, and E. B. Hart. The role of riboflavin in blood regeneration. J. Biol. Chem. *150:* 75. 1943.
142. Stanley, A. J., H. C. Hopps, and A. A. Hellbaum. Observations on cobalt polycythemia. I. Studies on the peripheral blood of rats. Proc. Soc. Exptl. Biol. Med. *61:* 130. 1946.
143. Steenbock, H., E. M. Nelson, and E. B. Hart. Fat soluble vitamin. IX. The incidence of an ophthalmic reaction in dogs fed a fat soluble vitamin deficient diet. Am. J. Physiol. *58:* 14. 1921.
144. Stimson, A. M. and O. W. Hedley. Observations on vitamin A deficiency in dogs. U.S. Pub. Health Repts. *48:* 445. 1933.
145. Street, H. R. and G. R. Cowgill. The cure of canine blacktongue with nicotinic acid. Proc. Soc. Exptl. Biol. Med. *37:* 547. 1937.
146. Street, H. R. and G. R. Cowgill. Acute riboflavin deficiency in the dog. Am. J. Physiol. *125:* 323. 1939.
147. Street, H. R., G. R. Cowgill, and H. M. Zimmerman. Vitamin $B_6$ deficiency in the dog. J. Nutrition *21:* 275. 1941.
148. Street, H. R., G. R. Cowgill, and H. M. Zimmerman. Further observations of riboflavin deficiency of the dog. J. Nutrition *22:* 7. 1941.
149. Street, H. R., H. M. Zimmerman, G. R. Cowgill, H. E. Hoff, and J. C. Fox, Jr. Some effects produced by long-continued subminimal intakes of vitamin $B_1$. Yale J. Biol. and Med. *13:* 3. 1941.
150. Turner, R. G. Effect of prolonged feeding of raw carrots on vitamin A content of liver and kidneys in the dog. Proc. Soc. Exptl. Biol. Med. *31:* 866. 1934.
151. Udall, R. H. and C. M. McCay. The feed value of fresh bone. J. Nutrition *49:* 197. 1953.
152. Voegtlin, C. and G. C. Lake. Experimental mammalian polyneuritis produced by a deficient diet. Am. J. Physiol. *47:* 558. 1919.
153. Wakerlin, G. E., W. G. Moss, and E. L. Smith. Treatment of experimental renal hypertension with vitamin A. Science *96:* 161. 1942.
154. West, R. Inhibition by sulfapyridine of the curative action of nicotinic acid in dogs. Proc. Soc. Exptl. Biol. Med. *46:* 369. 1941.
155. Yurtaev, G. I., II. Experimental vitamin $B_6$ deficiency in dogs. Trudy Inst. Eksptl. Med. Akad. Nauk Latv. S.S.R. 1, 87: Chem. Abst. *53:* 15248H. 1959.