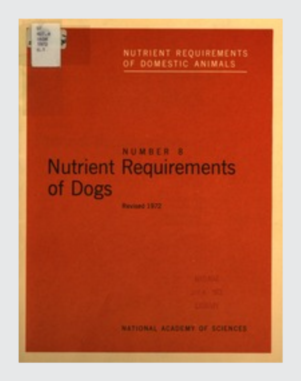

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Nutrient Requirements of Dogs

Revised 1974

Subcommittee on Dog Nutrition
Committee on Animal Nutrition
Board on Agriculture and
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National Research Council

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PREFACE

This report is one of a series issued under the direction of the Committee on Animal Nutrition, Board on Agriculture and Renewable Resources, National Research Council. It was prepared by the Subcommittee on Dog Nutrition, and it replaces *Nutrient Requirements of Dogs*, issued in 1972.

Statements on nutrient requirements are accompanied by descriptions of the common signs of deficiency. The tables include nutrient requirement values that provide for adequate nutrition of both growing puppies and adult dogs.

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INTRODUCTION

Dogs require energy, amino acids, fatty acids, glucose precursors, minerals, and vitamins. These may be supplied by purified diets or by appropriate combinations of natural feedstuffs. When properly processed and supplemented, both plant and animal products are suitable.

Nutrient requirements of dogs are expressed as percentages or units per kilogram of diet in Table 1 and as units per kilogram of body weight per day in Table 2. These figures represent the Subcommittee's best judgment based on currently available information on dogs and other species and are designed to provide the nutrients required for the entire life cycle of all breeds of dogs (including support of normal growth as shown in Figure 1). They are intended only as guides, however, and may need to be modified as circumstances and experience warrant.

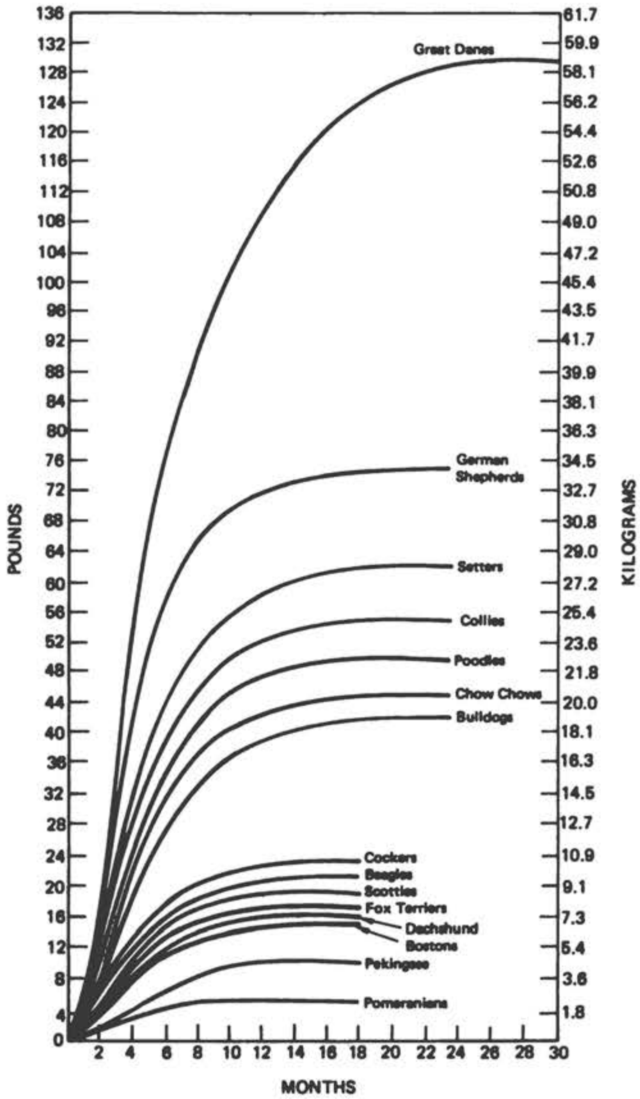

FIGURE 1 Growth curves for fifteen breeds of dogs. *Courtesy of R. W. Kirk, Cornell University, Ithaca, New York. Adapted from Current Veterinary Therapy III. 1966. W. B. Saunders & Co., Philadelphia, p. 716.*

NUTRIENT REQUIREMENTS AND SIGNS OF DEFICIENCY

ENERGY

Food provides not only specific nutrients but also energy for support of metabolism and maintenance of body temperature. Harris (1966) has discussed biological energy interrelationships and defined the terms adopted by the National Research Council for various forms of biological energy. When food is oxidized completely in a bomb calorimeter, the total combustible energy released as heat is known as gross energy. Gross energy values for carbohydrates, fat, and protein average 4.15, 9.40, and 5.65 kcal/g, respectively. However, not all of the gross energy contained in food is available for support of metabolism. Some is lost during digestion and appears in the feces. The difference between the gross energy consumed and that in the feces is known as apparent digestible energy. Of the apparent digestible energy, a significant fraction appears in the urine. The approximate metabolizable energy values remaining are 4 kcal/g for carbohydrate or protein and 9 kcal/g for fat. Specific metabolizable energy values for individual feedstuffs are given in Table 6.

Mature body weights of dogs range from 1 kg for the Chihuahua to 90 kg for the St. Bernard. It has been determined that energy requirements are not directly related to body weight but more closely to body weight raised to some power, W^b, where W equals weight in kilograms and b is an exponent calculated from experimental data. Brody *et al.* (1934) found that the basal heat production of mature warm blooded animals, ranging in size from mice to elephants, could be described by the expression $Y = 70.5\ W^{0.73}$ where Y equals kilocalories per 24 h and W equals body weight in kilograms. Kleiber (1961) argued that, over such a range in body size, Brody's expression and $Y = 70\ W^{3/4}$ would not be significantly different, and the latter would be simpler to use. Kleiber's position has been generally accepted, and this expression has been used as the basis for estimates of basal metabolic energy needs of mature dogs. The power function of body weight, $W^{3/4}$, is termed metabolic body size. For convenience the expression will subsequently appear as $W^{0.75}$, even though this implies greater than actual precision. A table of weight conversions to $W^{0.75}$ is available in Publication 1411 of the National Academy of Sciences (Harris, 1966).

Requirements for Adult Maintenance

Energy requirements for maintenance of adult dogs have been studied by Cowgill (1928) and estimated by Arnold and Elvehjem (1939) from prediction values of Brody *et al.* (1934). Abrams (1962) also published estimates of maintenance energy requirements of adult male dogs that conform closely to previous figures, although it is not clear how these data were derived. Payne (1965), using Abram's data, published estimates of metabolizable energy (ME) requirements for maintenance of adult, growing, pregnant, and lactating dogs. These estimates have been modified to express the requirements in terms of metabolic body size ($W_{kg}^{0.75}$) and are presented in Table 3. While these figures can serve as guides, energy requirements also vary with age, body condition, activity, insulative characteristics of the hair coat, environmental circumstances and temperature acclimatization. Generally, adult dogs appear to adjust their food intake to energy needs. This observation was confirmed by Cowgill (1928) who found that dogs that had adjusted to an appropriate intake of a particular diet consumed fewer grams, but the same number of calories, of a diet with a higher energy density. Durrer and Hannon (1962), working in an arctic environment with Beagles procured in northern California and with Alaskan Huskies, found that caloric intakes varied inversely with long-term changes in environmental temperature. In July, when the mean temperature was

17 °C, Beagles consumed approximately 163 kcal of ME per $W_{kg}^{0.75}$ per day, while Huskies consumed 127. In November, when mean temperatures were −17 °C, the respective daily ME intakes for Beagles and Huskies were 278 and 205 kcal per $W_{kg}^{0.75}$. The Huskies exhibited a marked increase in hair growth during November and December, while little seasonal change in hair growth was seen in the Beagles. Both breeds minimized heat loss during extremely cold weather (less than −40 °C) by curling into a "ball" and tucking their nose and tail underneath their body. While the Huskies showed no evidence of shivering and refused to sleep in plywood shelters, the Beagles shivered and sought shelter. While weight changes were small, both breeds tended to be heavier in the summer than in the winter, suggesting that adjustment of intake lagged behind caloric requirements.

Requirements for Growth

Growing puppies of a given breed require about 2-times as much energy per unit of body weight as adult dogs of the same breed. In their studies of Airdales, Arnold and Elvehjem (1939) found that puppies fed 1.5-times the estimated adult maintenance requirements per unit of body weight did not gain satisfactorily, while puppies fed 2.5-times maintenance requirements became fat.

Requirements for Reproduction and Lactation

Bitches require slightly more energy during gestation than during maintenance. Most of this increased demand develops during the last trimester of pregnancy. During heavy lactation, energy requirements greatly increase and may reach 3- or more times maintenance needs.

Requirements for Muscular Activity

Increased muscular activity associated with hunting or racing also may greatly increase energy demand. For sled dogs in a cold environment, 3-times maintenance energy intakes may be required to maintain body weight (Orr, 1965).

Nutrient–Energy Interrelationships and Food Consumption

Since dogs tend to consume well-balanced dry diets in relation to their energy needs (Cowgill, 1928), it is important that the concentration of nutrients in the diet be proportional to metabolizable energy concentration rather than to diet weight. Thus, diets that are high in fat and, consequently, high in metabolizable energy concentration will be consumed in somewhat smaller amounts and should contain higher percentages of protein, minerals, and vitamins than diets that are less concentrated in energy. This concept is illustrated in Table 3 where protein requirements are expressed in relation to metabolizable energy needs rather than as a percent of the diet. The protein value of the diet is expressed as Net Dietary-protein Calories percent (ND$_p$ Cal %), which is defined as follows (Platt *et al.*, 1961):

$$\text{ND}_p\text{ Cal }\% = \frac{\text{retained dietary protein (expressed in kcal ME)}}{\text{total ME in food consumed}} \times 100$$

$$= \frac{\text{retained dietary N (g)} \times 6.25 \times 4\text{ kcal}}{\text{total food intake (g)} \times \text{ME in food (kcal/g)}} \times 100$$

Palatability can influence the amount of food, and consequently the amount of metabolizable energy, consumed. Most dogs can be fed dry diets *ad libitum*, with water offered in a separate dish, without excessive consumption leading to obesity. When dogs are meal-fed dry diets to which water is added, or semimoist or canned dog foods, it may be necessary to limit the amount offered to the suggested food intakes in Table 4. Individual dogs may vary from these standards in their requirements and should be fed accordingly.

Signs of Deficiency

Signs of deficiency are frequently nonspecific, and diagnosis may be complicated by a simultaneous shortage of several nutrients. The most conspicuous and reliable sign of uncomplicated energy deficiency is subnormal body weight. Parasitism and bacterial infections frequently occur under such circumstances and may superimpose other clinical signs. Under conditions of partial or complete starvation, most internal organs exhibit some atrophy. The brain is least affected in size, but the gonads may be strikingly decreased. Hypoplasia of lymph nodes, spleen, and thymus leads to a marked reduction in their size. The adrenal glands are usually enlarged. The young skeleton is extremely sensitive to energy deficiency, and growth is inhibited or completely stopped. In the adult, the skeleton may become osteoporotic. A loss of subcutaneous, mesenteric, perirenal, uterine, testicular, and retroperitoneal fat is an early sign. Low fat content of the marrow in the long bones is a good indicator of prolonged inanition. Lactation and the ability to perform work are impaired, and endogenous nitrogen losses increase as muscle proteins are catabolized for energy.

CARBOHYDRATES

A minimum carbohydrate requirement for dogs has not been established. It is probable that dogs can be maintained without dietary carbohydrate if the diet furnishes fat (and thus glycerol) or protein (containing glucogenic amino acids) from which blood glucose may be derived. It should be noted, however, that Naismith and Cursiter (1972) found weanling rats grew more slowly on a carbohydrate-free diet, and there was more fat and less protein in their bodies as compared to rats consuming isocaloric amounts of a carbohydrate-containing diet. They also found that, when carbohydrate was excluded from the diet, protein that would normally have been used for growth was diverted to manufacture of glucose even when protein intake itself was unchanged. Luick *et al.* (1962) have obtained evidence with lactating Beagles that plasma glucose provides 68–100 percent of the carbon for lactose synthesis, 7.2–12 percent for milk protein, and 3.1–8.7 percent for milk fat. Thus, it is apparent that the catabolism of noncarbohydrate substances must be very important in maintaining the energy balance of bitches that are nursing large litters and fed little or no carbohydrate.

It has been well established that the dog can effectively utilize dietary carbohydrates. The nursing puppy obviously utilizes lactose, although Luick *et al.* (1960) pointed out that lactose supplies only 8 percent of the metabolizable energy in milk of Beagles, while in cow and human milk it supplies 27 and 41 percent, respectively. Cajori (1935) found significant lactase activity in the mucosa of the duodenum and jejunum of adult dogs and small amounts in dog liver. However, when adult dogs accustomed to little or no dietary lactose are given large amounts suddenly, they may exhibit diarrhea and measurable amounts of lactose and galactose in their urine (Bennett and Coon, 1966).

Bennett and Coon (1966) showed that adult dogs can utilize dextrin-maltose, glucose, and sucrose when these substances are suddenly introduced, but large amounts (54% of diet ME calories) of the latter sugar resulted in measurable urinary sucrose and fructose. Research with other species (Becker *et al.*, 1954) would suggest that sucrose should not be used in artificial milks for puppies because there may be low intestinal sucrase activity during the immediate postnatal period and also a limited ability to convert fructose to glucose.

Roseboom and Patton (1929) found significant amylase activity in the secretions of the dog submaxillary salivary gland and pancreas. These workers found that starch in boiled macaroni was completely digested when fed in moderate amounts (up to 175 g/d to an adult 15-kg dog). Likewise they reported (Roseboom and Patton, 1932) that 75 g/d of cornstarch was completely digested by an adult 15-kg dog. Ivy *et al.* (1936) found that adult dogs completely digested starch derived from cooked farina in a diet containing 62 percent of this carbohydrate. These workers also presented evidence that oral administration of vegetable diastase may be helpful in overcoming inadequate pancreatic amylase production (Beazell *et al.*, 1937). James and McCay (1950) fed a diet containing 33-percent toasted corn flakes and 23-percent toasted wheat flakes, as the only source of starch to adult Salukis, German Shepherds, and Basset Hounds, and found that 98 percent of the starch was digested. McCay (1949) noted that farm dogs may consume appreciable amounts of raw starch in livestock feeds without apparent ill effect. However, McCay and others have observed that large amounts of raw starch may lead to diarrhea and flatulence. This is probably due in part to the fermentation, by bacteria in the large intestine, of carbohydrate escaping small intestinal digestion. Heiman (1959) stated that the digestibility of raw corn was increased 17 percent by cooking and toasting. Experience shows that the suitability of starch sources—such as corn, wheat, pearled barley, oat groats, or potatoes—is enhanced by cooking, baking, toasting, or other processes resulting in some dextrinization.

FAT

Dietary fat serves as a concentrated source of energy, provides essential fatty acids (which serve structural functions in cell membranes and metabolic functions, e.g., as precursors of prostaglandins), is a carrier of fat-soluble vitamins, and lends palatability and a desirable texture to dog food.

Analytical Procedures

Materials that are extractable from dog food with anhydrous diethyl ether are termed crude fat and primarily include glycerides of fatty acids, although small amounts of other substances—such as chlorophyll or xanthophylls, which have no nutritional significance—may also be found. Unless ether extraction is preceded by acid hydrolysis, the glycerides in baked or expanded dog food will not be completely released, and estimates of fat may be 50–100-percent too low (Budde, 1952; Hoffman, 1953). The fats (including phospholipids) in certain animal products are more completely extracted by a chloroform–methanol mixture; thus, ether extraction procedures may also lead to underestimates of the energy potential of these feed ingredients.

Digestibility

Digestibility of dietary fat will vary with source and processing. Using a diet for adult dogs containing 33-

percent corn flakes, 23-percent wheat flakes, 10-percent meat meal, 10-percent liver meal, 5-percent soybean meal, 4-percent dry skim milk, 4-percent wheat germ, and lesser amounts of other ingredients (none containing significant fat)—James and McCay (1950) found the apparent digestibility of fat varied from 79–95 percent, with a mean of 84 percent. Orr (1965) reported that the apparent digestibilities of fat in Pemmican (beef base), Nutrican (whale meat base), and seal for adult sled dogs were 97, 87, and 88 percent, respectively. Wikoff *et al.* (1947) fed a variety of saturated fats and fatty acids to dogs, with variable effects on fecal volume and composition, dependent upon the substance fed. No meaningful estimates of fat digestibility were developed, but these authors concluded that the effect of a high-fat diet on intestinal elimination depends, at least partially, on the component acids of the fat intake. Diarrhea resulted from the feeding of diets containing caprylic, caproic or butyric acids or their glycerides. A mild constipation followed feeding of stearic acid or tristearin. Trilaurin produced diarrhea, but fecal elimination was normal after feeding lauric acid.

When dietary fat consists primarily of the mixture of glycerides associated with supplements of vegetable oils or animal fats used in modern dog diets, apparent digestibilities of 90–95 percent may be expected.

Dietary Fat Level

Because the metabolizable energy concentration of digestible fat is approximately 2.25-times the ME concentration of digestible carbohydrate or protein, substitution of fat for these other nutrients in the dog diet may increase the energy density of the diet appreciably. Cowgill (1928) found that the dog generally responds by eating less of this high energy diet as compared to a lower energy diet, but the ME intake is about the same. If the percentages of protein, minerals, and vitamins in the high-energy diet are not appropriately increased, the daily intake of energy may be adequate; however, the daily intake of protein, minerals, and vitamins may not be (Elvehjem and Krehl, 1947; Ontko *et al.*, 1957; Crampton, 1964).

Extremely wide variations in fat intake appear generally compatible with health if essential fatty acid and other nutrient requirements are met. Siedler and Schweigert (1952) fed a diet containing 3.9-percent ether extract (dry basis) to growing puppies while Orr (1965) fed seal meat (skin, blubber, and lean meat) containing 66-percent ether extract (dry basis) to adult dogs. Both groups of dogs appeared normal. Morgan (1935, 1940) fed diets containing 10–24-percent fat for 2 years without producing harmful effects. Ivy (1936) and Axelrod *et al.* (1951) refer to dogs that tolerated 40-percent fat in their diets. Campbell and Phillips (1953) reported that high dietary fat caused reduced food intake and retarded growth in puppies. They established, however, that these effects could be corrected by adjusting the intake of essential amino acids to balance the increased intake of energy. It should be noted, nevertheless, that evidence exists that obesity (Newberne, 1966) or a diet high in fat (Fiser *et al.*, 1972) may increase susceptibility of the dog to infectious disease.

Dogs are maintained successfully on dry diets containing 5–8-percent fat (Linton, 1934). Siedler and Schweigert (1952, 1954) described experiments in which 4 percent of choice white grease was added to a diet already containing 3.7-percent fat. This diet produced satisfactory growth in Cocker Spaniel puppies. Reproductive performance was somewhat better for bitches fed this diet (total fat, 7.7 percent) than for those fed a diet with a total fat content of 11.7 percent. Ontko and Phillips (1958) found that 8-percent cottonseed oil in the diet was satisfactory for reproduction.

The use of high concentrations of unsaturated fats may lead to rancidity and to destruction of other nutrients, such as vitamin E. Properly stabilized, partially hydrogenated soybean oil was used for deep-fat frying and was then fed to dogs as 15 percent of the diet. It was found to be wholesome and nutritious but somewhat lower in absorbability and linoleic acid content and higher in peroxides than fresh soybean oil (Nolen, 1973). When Hayes *et al.* (1969) fed a diet that was up to 15-percent safflower oil to puppies without supplemental vitamin E, signs of vitamin E deficiency appeared and were more severe at the higher unsaturated fat intakes. Supplementation with 11 mg of d-α-tocopheryl acetate per kilogram of body weight per day prevented the lesions—probably because the tocopherol–polyunsaturated fatty acid ratio (mg/g) was greater than 2.0 in the diets of all supplemented dogs. Harris and Embree (1963) have recommended that this ratio be at least 0.6, while this Committee suggests a ratio of at least 0.5 to ensure that the needs for vitamin E will be met. The proportions of saturated and unsaturated fatty acids found in dog food ingredients are shown in Table 5.

Essential Fatty Acids

Apart from considerations of diet palatability, the minimum required level of dietary fat depends on its fatty acid composition. If the diet is very low in fat or if the fat is completely saturated, skin lesions appear (Hansen *et al.*, 1948, 1954; Hansen and Wiese, 1951; Wiese *et al.*, 1965, 1966), which can be prevented or cured by linoleic acid, γ-linolenic acid, or arachidonic acid. Because they cannot be synthesized from other dietary components, these fatty acids are considered essential. However, they are interconvertible within the tissues (Steinberg *et al.*, 1956); thus, if any one of the three is present in adequate amounts, the essential fatty acid requirement will be met. Arachidonic acid and γ-linolenic are not major components of natural fats; hence, the effectiveness of dietary fat in preventing and curing a fatty acid deficiency is usually related to its linoleic acid content. The linoleic acid concentrations of a variety of ingredients used in dog foods are shown in Table 5.

The minimum amount of linoleic acid (or other essential fatty acids) required by the dog has not been precisely determined. The pathological and biochemical changes in the skin produced by an essential fatty acid deficiency can be reversed when 2–6 percent of the ME requirement is provided by linoleic or arachidonic acid (Hansen and Wiese, 1951; Weise *et al.*, 1966). One percent of the ME requirement as linoleic acid does not appear to be adequate for growing puppies (Wiese *et al.*, 1966). The rate of growth influences the development of fatty acid deficiency (Wiese *et al.*, 1962), with lesions appearing in 2–3 months in Beagle puppies receiving a low-fat diet providing 200 kcal ME per kilogram of body weight per day and in 3–4 months when puppies received 150 kcal ME per kilogram of body weight per day. Puppies receiving 100 kcal ME per kilogram of body weight per day did not grow, nor did they exhibit gross or histological evidence of fatty acid deficiency during the 5-month study. Two percent of the ME intake as linoleic acid was sufficient to prevent deficiency lesions in all puppies. This would constitute about 1 percent of the dry solids of the typical dog diet, and is recommended as a minimum linoleic acid value. The fact that the arachidonic acid level in the skin is significantly higher in newborn puppies than later in life, suggests that essential fatty acids may also be important in the diet of the pregnant bitch (Wiese *et al.*, 1966).

Recommendation

It is recommended that a dog food contain at least 5-percent fat on a dry basis, including 1 percent of the diet as linoleic acid. Since not all fats are rich in linoleic acid (Table 5), supplemental fats must be chosen judiciously when total fat is only 5 percent. While these levels appear sufficient for normal physiological functions, higher fat levels may be desirable in practical dog foods to enhance acceptability and to improve hair coat sheen. If such increases are made, the concentrations of other noncarbohydrate nutrients should also be appropriately increased.

Signs of Deficiency

Puppies on a low-fat diet (probably $<0.01\%$ linoleic acid), but with a high caloric intake per day, began to show coarse, dry hair and desquamation on the ventrum after 2–3 months. After 4–5 months (6–7 months of age), these lesions were severe. At a normal caloric intake, lesions appeared about 1 month later (Wiese *et al.*, 1962). The earliest gross lesions appeared on the abdomen, then on the thigh, and last in the interscapular area. Histologically, the epidermis was edematous and thickened, with up to 12 layers of cells in the most severely affected areas. Keratinization was deranged and, as the deficiency advanced, parakeratosis became evident. Maturation of the epidermal cells seemed impaired. Affected areas were invaded first by mononuclear cells, followed later by polymorphonuclear neutrophils. The epidermis appeared ulcerated and was more susceptible to infection. Both the sebaceous and sudoriparous glands were more active. Linoleic acid and arachidonic acid levels in the skin decreased markedly. (See Figure 2.)

PROTEIN

Dogs need dietary protein to supply specific amino acids that their tissues cannot synthesize at a sufficient rate for optimum performance. Rose and Rice (1939) established that the following amino acids are dietary essentials to maintain nitrogen equilibrium in adult female dogs:

- histidine
- isoleucine
- leucine
- lysine
- methionine
- phenylalanine
- threonine
- tryptophan
- valine

Based on research with other species, it is probable that these amino acids, plus arginine, are dietary essentials for growth of puppies. Preformed cystine and tyrosine will undoubtedly meet some of the needs for methionine and phenylalanine, respectively, in the diets of puppies or adult dogs.

The percentage of protein required in the diet depends upon protein digestibility, amino acid composition, caloric density of the diet and physiological state of the dog. Estimates of protein requirements can also vary with the methods and criteria used in their derivation.

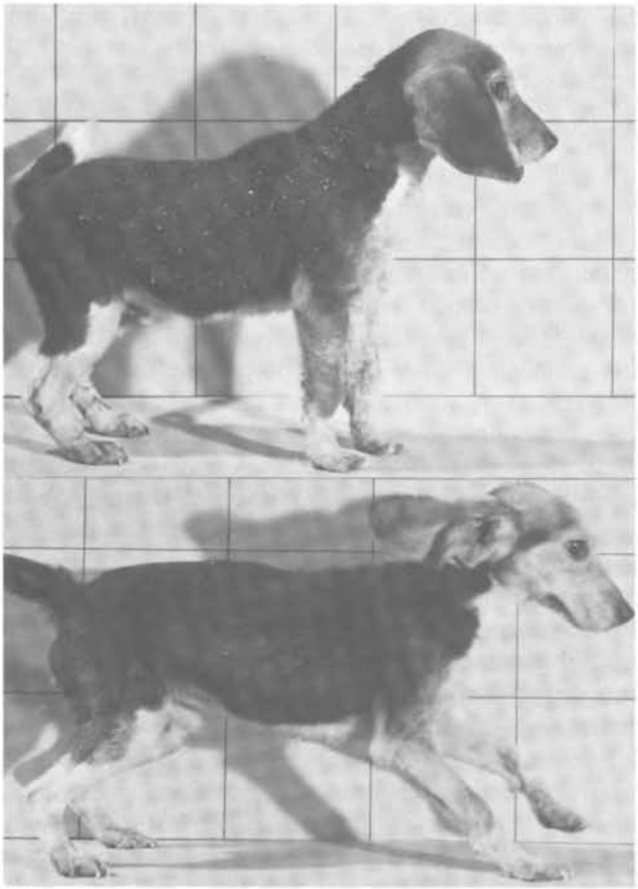

FIGURE 2 Fat deficiency. *Above:* Unkempt appearance and flaky desquamation result from 4½ months of a fat-deficient diet; age 6 months. *Below:* Same dog after addition of 1 percent kcal as trilinolein for 2½ months and 6 percent kcal as linoleate (safflower oil) for 7 weeks; age 12 months.
Courtesy of H. F. Wiese, Bruce Lyon Memorial Research Laboratory, Children's Hospital Medical Center, Oakland, California.

Digestibility

Few data have been published on the digestibility of various dietary proteins by the dog. Hegsted *et al.* (1947) found the apparent digestibility of proteins in an all-vegetable diet fed to adult dogs was 80.0 ± 7.7 percent (mean ± standard deviation). The percentages of total protein in this diet which were provided from various ingredients were as follows: white bread, 50; corn, 7.6; rice, 4.4; potatoes, 13.3; lettuce, carrots, onions, and tomatoes, 16.3; and orange juice, applesauce, and peaches, 8.4. When one-third of each dietary ingredient was removed and its amount of protein replaced by an equivalent amount of protein from meat, the apparent digestibility of the total protein in the diet increased to 90.3 ± 7.1 percent. James and McCay (1950) reported that the apparent protein digestibility of a commercial dry-type food, containing both vegetable and animal proteins ranged from 67 to 82 percent (mean 74%) for adult dogs.

Requirements for Adult Maintenance

The required concentration in the diet of a particular protein is determined by how well it supplies the amino acid needs of the tissues. The more closely these needs are approached, the lower will be the percentage of the protein required in the dog's diet (Allison *et al.*, 1947; Kade *et al.*, 1948; Arnold and Schad, 1954). Working with protein-depleted adult dogs weighing from 6 to 13.5 kg, Kade *et al.* (1948) found that a daily intake of 90 mg of nitrogen from lactalbumin per kilogram of body weight was adequate for nitrogen equilibrium. When casein was fed, 140 mg of nitrogen per kilogram of body weight was required. This value was reduced to 90 when the casein was supplemented with methionine. Arnold and Schad (1954) reported similar findings with adult protein-depleted dogs weighing 6.2–18.6 kg. Using casein alone, a median intake of 139 mg of nitrogen per kilogram of body weight per day was required for nitrogen equilibrium. When 1 or 3 g of DL-methionine were added to 100 g of casein protein ($N \times 6.25$), median nitrogen intakes for nitrogen balance dropped to 102 or 72, respectively. The latter workers concluded that the sulfur amino acid requirement was about 30 mg/kg of body weight per day, when the sulfur amino acid component contained about 89-percent methionine and 11-percent cystine. When their data were expressed as a fraction of the air-dry diet, the percentages of protein ($N \times 6.25$) necessary for nitrogen balance were 6.5 for unsupplemented casein, 5.2 for casein supplemented with 1-percent methionine and 4.8 for casein supplemented with 3-percent methionine.

Voit (1881) recognized long ago that different minima exist with respect to the protein intake necessary to maintain nitrogen equilibrium, and Cathcart (1921) stated "that the search for an absolute minimum is like the search of the philosopher for absolute truth. There is not one minimum but many protein minima—[each] a resultant of many factors." Adult dogs, not intensively depleted of their protein reserves, require about 12-percent dietary protein from casein to maintain nitrogen equilibrium (Melnick and Cowgill, 1937). When the dietary requirements for lactalbumin, beef serum proteins, casein and gliadin were expressed as a percent of ME intake (using 4 kcal/g for carbohydrate and protein, and 9 kcal/g for fat), the values were found to be 6.9, 8.6, 9.4 and 21.1 percent, respectively. When compared to known amino acid requirements for other species and the probable amino acid composition of these protein sources (Block and Weiss, 1956), beef serum proteins and casein were first limiting in methionine, while gliadin was first limiting in lysine. As a consequence, the dietary concentration of these more poorly balanced proteins, as compared to lactalbumin, had to be increased to provide the minimum requirement of the first limiting amino acid.

Protein reserves may be important in protecting the dog against a variety of stresses. Although 140 mg of casein nitrogen per kilogram of body weight per day (6.5% of the dry-type diet) will sustain nitrogen equilibrium in a protein-depleted dog, susceptibility to the toxic effects of phosphoramides (used in cancer chemotherapy) and 2-aminofluorene (a carcinogen) is greater than when the protein reserves are maintained by feeding 600 mg of casein nitrogen per kilogram of body weight per day (16% of the dry-type diet) (Allison *et al.*, 1954; McCoy *et al.*, 1956). Thus, the protein requirement for maintenance of the adult dog during stress may be higher than for nitrogen equilibrium in the nonstressed dog, and it may be desirable to provide a minimum of 17.8-percent protein (equivalent in quality to casein) in the 100-percent dry diet containing 3.5–4 kcal ME per gram.

Requirements for Growth

Studies on the protein requirements for growth of puppies have been reported by Heiman (1947), Gessert and Phillips (1956), and Ontko *et al.* (1957). Heiman allowed Cocker Spaniel puppies weaned at 6 weeks to adjust to a dry-type diet for 1 or 2 weeks before assignment to other dietary treatments. They were fed three times daily for the first 8 or 15 weeks and twice daily thereafter until 28 or 32 weeks in two experiments. The protein concentrations of the diets were varied by substituting a protein mixture containing 15-percent fish meal, 46-percent meat meal, and 39-percent soybean meal for a carbohydrate mixture containing cooked, flaked cereals. The conclusion—based upon weight gain and appearance—was that a 20-percent protein air-dry diet was adequate, while one that was 17-percent protein was not. A third study, with English Setter puppies from 9 to 23 weeks of age, revealed no difference in weight gain or condition between 23- and 27-percent protein. Lower protein levels were not studied.

Gessert and Phillips (1956) fed Beagle and mongrel (predominantly Collie) puppies a dry-type diet from 6 to 7 weeks of age for 14 weeks or more. The basal diet contained 10–11 percent of a "well balanced protein," and protein levels of 12.8, 15.0, 17.2, and 19.4 percent were achieved by substituting casein for sucrose. These diets contained about 7.5-percent fat. The calculated ME concentration, using data from Table 6 of this publication, was 3.38 kcal/g. Weight gain and appearance were considered satisfactory on a 17.2-percent protein diet.

The need for dietary protein (and amino acids) is related to the energy concentration of the diet. Campbell and Phillips (1953) noted that adding fat to a 19.7-percent protein diet inhibited growth of growing puppies. Normal growth resumed when 0.3-percent methionine was added. Ontko *et al.* (1957) estimated the dietary protein requirements of growing Beagle, Shepherd, and Shepherd–Collie puppies fed a dry-type diet containing either 20- or 30-percent fat (4.02 or 4.57 kcal ME/g calculated from Table 6). The puppies were fed their respective diets from about 7 weeks of age for a period of 10 weeks. The conclusion—based on weight gain, feed efficiency, and physical condition—was that 25.0-percent protein was required in the diet containing 20-percent fat, and 28.9 percent if the fat content was 30 percent. If one assumed that the dry matter concentration of the diets fed by Ontko *et al.* was 90 percent, then protein requirements for growth and dietary ME concentrations, expressed on a dry matter basis, were related as follows:

ME, kcal/g	Protein Requirement, %
3.76	19.1
4.47	27.8
5.08	32.1

Requirements for Reproduction and Lactation

The protein and amino acid needs for reproduction and lactation have not been well defined. Ontko and Phillips (1958) fed a semipurified diet containing 20-percent casein, 66-percent sucrose, 8-percent cottonseed oil, and minerals and vitamins to mature Beagle and Cocker Spaniel bitches for over 2½ years. Supplements of 10-percent fresh liver, 5-percent casein, 2-percent liver extract, or 5-percent autoclaved egg white improved the vigor of their newborn pups and reduced postnatal mortality. Supplementation with 0.3-percent DL-methionine did not elicit this response, but a 5-percent addition of alcohol-extracted casein was just as effective as untreated casein. Unfortunately, pup mortality ranged from 22 to 35 percent even on the supplemented diet. Research with other species and practical experience with dogs indicate that the amino acid requirements for reproduction and lactation, expressed as a percent of the diet, do not exceed those for growth. Thus, it is probable that 22-percent protein (equivalent in quality to casein) in the 100-percent dry diet containing 3.5–4 kcal ME per gram will meet the needs for reproduction and lactation.

Requirements for Muscular Activity

Protein requirements of the working dog have not been established. Research with other species suggests that, if the energy requirements are met, protein needs are no greater than for maintenance. Hard work may reduce food intake as a consequence of overwhelming fatigue. In order to encourage adequate food intake in hard-working dogs, it may be necessary to increase palatability of the diet. If this is done by adding fat, protein concentration must be increased proportionately to maintain an appropriate protein–calorie ratio.

Requirements for Old Age

Wannemacher and McCoy (1966) established that both young dogs (1-year-olds) and old dogs (12–13-year-olds) can be placed in nitrogen equilibrium and maintained with 200–600 mg of casein nitrogen per kilogram of body weight per day. Liver and muscle protein-to-DNA ratios reached maximal values in young dogs fed 400 mg of casein nitrogen per kilogram of body weight per day, while older dogs required 600 mg. The consumption of larger quantities of casein did not produce a further increase in reserve protein. These results, and a significantly lower rate of incorporation of leucine into liver and muscle protein of older dogs, suggest that age may be associated with less efficient cellular protein anabolism. The conclusion, based upon this study, was that 17.8-percent protein (equivalent in quality to casein) in the 100-percent dry diet containing 3.5–4 kcal ME per gram should meet the needs of the old dog.

Signs of Deficiency

Deficiency signs may result from an inadequate intake of either high-quality protein or of a particular essential amino acid. The deficiency effects are generally nonspecific, and many of the signs cannot be distinguished from the effects of partial or total caloric restriction. In addition to poor growth and weight loss, there may be depressed appetite, decreased formation of hemoglobin, erythrocytes, and plasma proteins. Edema is sometimes associated with the hypoproteinemia that results. Milk production is decreased; the hair coat is rough and dull in appearance; and antibody formation is impaired. Tissue protein-to-DNA ratios decline, and associated with this decline in protein reserves is an increased susceptibility to the effects of toxic compounds and cancer-producing agents.

MINERALS

Dogs require calcium, phosphorus, iron, copper, potassium, magnesium, sodium, chlorine, iodine, manganese, zinc, selenium, and—perhaps—molybdenum, fluorine, tin, silicon, cobalt, nickel, vanadium, and chromium. Because there is insufficient experimental evidence, requirements for some of these minerals cannot be stated precisely. Many of the published guidelines for formulating diets adequate in minerals for dogs are based on estimates or have been derived from data for other species. The concentrations in Table 1 may be related to daily requirements in Table 2 by assuming 22 g of dry matter consumption per kilogram of body weight per day by adult dogs for maintenance and double this amount for growing puppies. Although the mineral requirements for gestation, lactation, and muscular effort have not been well defined, these needs are generally related to energy intake. As energy intakes increase in relation to the extra demands of milk production or exercise, daily intakes of minerals will also increase. The nutrient requirements in Table 1 have been set to meet the needs of the entire life cycle of the dog.

Calcium and Phosphorus

Requirements Calcium and phosphorus requirements are closely related and must be considered together. A calcium–phosphorus ratio of 1.2–1.4:1 (by weight) is considered optimal for utilization of these two minerals by dogs. An optimum calcium–phosphorus ratio also minimizes the vitamin D requirement. Availability of calcium and phosphorus is likewise of major importance (Schedle *et al.*, 1968). It is well known that diets high in phytates or low in vitamin D adversely influence calcium absorption (Mellanby, 1920; Hoff-Jørgensen, 1946); however, vitamin D supplementation of diets low in calcium caused pathological fractures, lameness, an abnormal stance, and loss of skeletal density (Campbell, 1962).

In a study of the calcium–phosphorus ratio in relation to periodontal diseases, Henrikson (1968) fed adult Beagle dogs a purified diet containing 0.12-percent calcium and 1.20-percent phosphorus. The progressive loss of alveolar bone was so severe that, by 12 months, the incisor teeth became easily detached. Histopathological examination revealed progressive parathyroid changes associated with hyperfunction. Such changes were not observed in control groups fed 0.54-percent calcium and 0.42-percent phosphorus. These findings agree with those of Jenkins and Phillips (1960b), who found that diets containing 0.6-percent calcium were adequate.

The amount of calcium and phosphorus retained varies with age. Hoff-Jørgensen (1946), working with two puppies at a starting age of 30 days, found that even when 1 g of each of these minerals was supplied daily, only 0.2–0.3 g of calcium was absorbed. The amount of calcium or phosphorus retained averaged slightly less than 0.2–0.3 g daily through the first 200 days of age despite an approximately sixfold increase in body weight. Retention tended to be slightly higher during the third and fourth months than at other times in the growth period. The highest retention of calcium observed during the experiment was about 160 mg/kg of body weight per day. The average was about 75 mg. Addition of phytic acid to the diet decreased absorption and retention of calcium but increased absorption and retention of phosphorus. Hoff-Jørgensen postulated that phytate caused the precipitation of calcium in the intestinal lumen as insoluble calcium phytate.

Morgan (1934) reported that diets supplying about 0.50-percent calcium and 0.65-percent phosphorus permitted normal bone development in some dogs that had been supplied with adequate vitamin D. Other dogs, mainly of larger breeds, developed signs of mild rickets when the calcium intakes were between 100 and 175 mg/kg of body weight per day. Retention ranged between 42 and 120 mg/kg of body weight per day. This was lower than reported by Hoff-Jørgensen (1946), who fed diets higher in calcium to dogs weighing 0.9–5.3 kg. The latter retention rates of 200–300 mg/d are in good agreement with those obtained by Udall and McCay (1953) with young Beagles fed fresh bone.

Jenkins and Phillips (1960b) found that growing puppies required 0.37-percent available calcium (0.60-percent total calcium) in the diet for normal growth and for mineralization of the skeleton. Increasing the dietary fat from 3 to 20 percent did not influence the calcium requirement. These studies indicate that about 0.75-percent total calcium in the diet would suffice if 50 percent of it were utilized. An assumption of 50-percent utilization may not apply to all situations, however, since Morgan (1934) found that retention ranged between 40 and 70 percent. In contrast, McCay (1949) noted that 60–80 percent of the calcium in the diets that he fed was utilized. Calcium that is not utilized is excreted mainly in the feces.

A diet consisting largely of cereal grains or grain products, and containing 2.25-percent calcium and 1.55-percent phosphorus, was extensively tested in dogs under hunting conditions and found satisfactory (Koehn, 1942). For reproduction in Foxhounds, this diet was rated as somewhat better than the other meal-type diets, which tended to be lower in calcium and phosphorus. Such a high dietary calcium concentration in the presence of high phytate may be expected to increase the dietary zinc requirements to 100 mg/kg or more.

Hedhammer *et al.* (1974) fed a diet to Great Dane puppies containing on a dry basis 36-percent protein, 14-percent fat, 40-percent carbohydrate, and 10-percent ash in a study of "overnutrition" and skeletal disease. *Ad libitum* food intakes were very large, and there were significant chondro-osseous changes, reflected in lameness and pain upon palpation of the skeleton, enlargement of the costochondral junctions and the epiphyseal–metaphyseal regions of long bones, hyperextension of the carpus and sinking of the metacarpo- and metatarsophalangeal joints. It may be significant that the diet contained (on a dry basis) 2.05-percent calcium, 1.44-percent phosphorus, 0.27-percent magnesium, and 4000 IU of vitamin D per kilogram—all appreciably in excess of presumed requirements.

When used as 4 percent of the diet, the salt mixture formulated by Phillips and Hart (1935) has supplied the mineral requirements of dogs under a variety of experimental conditions. The mixture provides a diet that contains about 0.5-percent calcium. For adult dogs, this is about 130 mg/kg of body weight per day; for puppies and lactating bitches, it may provide up to 3-times this amount.

Morgan (1934) fed diets providing 100–180 mg of phosphorus (average of 140 mg) per kilogram of body weight per day. Retention of phosphorus ranged from 12 to 43 percent and averaged 23 percent. Hoff-Jørgensen (1946) fed 1 g/d of phosphorus and reported that retention ranged from 18 to 38 percent. Jenkins and Phillips (1960a) found that a ration containing 0.33-percent dietary phosphorus provided the same amount of growth as a ration containing 0.53-percent phosphorus. Retention was 76 percent, which indicates a minimum requirement of 0.25 percent for available phosphorus. About 45 percent of the phosphorus was present as phytin phosphorus, and the calcium content was 0.60 percent. The phosphorus requirement increased by 10–15 percent when the calcium was increased to 0.9 or 1.2 percent. Increasing the dietary fat from 3 to 20 percent increased the phosphorus requirement about 20 percent. These observations indicate that the requirement for phosphorus would normally be met if the ration contained 0.5 percent of total phosphorus from other than plant sources, providing there was a desirable calcium–phosphorus ratio, and availability was 50 percent.

The calcium requirement shown in Table 1 is about 30-percent higher than that suggested by Arnold and Elvehjem (1939) and Jenkins and Phillips (1960b), and the phosphorus requirement is higher than reported by those authors. Such a margin of safety for dogs of various types and breeds appears reasonable. Unknown factors may adversely influence the utilization of minerals in many practical diets. Dogs of some types and breeds may perform satisfactorily on lower intakes of these minerals. Gershoff *et al.* (1958) maintained two dogs for 34 months on a purified diet that was only

0.11-percent calcium from the time they were 2–3 months of age. Compared to littermates fed a 0.63- or 1.23-percent calcium diet, no differences in fat-free bone ash or in growth rates were observed. The dietary calcium on the 0.11-percent calcium diet was 90-percent utilized compared to utilizations of 46 and 27 percent, respectively, when 0.63- or 1.23-percent calcium diets were fed. Under practical conditions, 90-percent utilization of calcium would not be expected, however. Gershoff *et al.* (1958) did not report analyses of phosphorus, but calculations based on published values show that the calcium–phosphorus ratio was about 0.2:1 on the lowest level. The authors concluded that the animals adapted to this diet. However, in view of Henrikson's (1968) studies with dogs beginning when the dogs were 1 year old, it seems probable that changes in mandibular bone would have resulted from the 0.11-percent calcium diet if fed over an extended period of time. Krook *et al.* (1971) have confirmed Henrikson's findings. Repletion with adequate calcium begins in the *laminae dura dentes* and is followed by the vertebrae and the long bones.

The conclusion, based upon practical experience and experimental data, was that diets containing 1.1-percent calcium and 0.9-percent phosphorus on a dry basis provide adequate supplies of these minerals for dogs.

Signs of Deficiency and Imbalance Adequate calcium and phosphorus nutrition depends on an adequate supply of available calcium and phosphorus, a suitable calcium–phosphorus ratio, and adequate vitamin D.

In dogs, calcium deficiency is associated with progressive parathyroid changes associated with hyperfunction (nutritional hyperparathyroidism). The rate of bone loss and osteoporosis depends on the skeletal region involved. Jawbones show earliest signs, followed by other skull bones, ribs, vertebrae, and finally the long bones. Loss of calcium from the jawbones can lead to recession of alveolar bone and recession of the gingiva. Detachment of the teeth and other early signs of deficiency may appear before compression of vertebrae and fractures of long bone. With rather severe calcium deficiency, the morphologic picture is characterized by excessive bone resorption, whereas defective mineralization of osteodystrophy seen in rickets is not readily observed except in the young animal.

Calcium deficiencies may result in tetany and convulsions, hemorrhage, reproductive failures, spontaneous fractures, and altered requirements for other nutrients, such as magnesium.

An uncomplicated deficiency of phosphorus seldom occurs in dogs except under experimental conditions. Low phosphorus intake will lead to rickets in young dogs, poor growth, and a depraved appetite. In adults, low phosphorus intakes lead to osteomalacia. Excessive intakes of phosphorus relative to calcium lead to signs of calcium deficiency. (See Figure 3.)

Iron and Copper

Requirements Ruegamer *et al.* (1946) maintained normal hemoglobin in Collie puppies that received 3 mg of iron as ferric pyrophosphate per kilogram of body weight per day. Other puppies, made anemic by an iron-free diet, did not recover when 0.4 mg of ferric pyrophosphate per kilogram of body weight was supplied daily, but they did recover when the supplement was increased to 0.6 mg/kg (equivalent to 0.2 mg of iron). When the supplement was increased to 1 mg, more iron was absorbed and utilized, but the percentage of utilization dropped from about 60 percent (0.6 mg/kg body weight level) to about 36 percent (1 mg/kg body weight level). One dog receiving 0.4 mg/kg of body weight of this supplement utilized 74 percent of the iron, but the intake was inadequate even though it was more efficiently utilized. Frost *et al.* (1940) also obtained 60–70-percent utilization of inorganic iron supplements and indicated that absorption may sometimes approach 100 percent. With intakes of 0.6 mg/kg of body weight per day, normal values of 100–200 μg of iron per 100 ml of plasma were found. When the smaller quantities were fed, plasma iron values were low.

On the basis of this evidence it would seem that 1.32 mg of dietary iron per kilogram of body weight per day should meet the needs of puppies, adult dogs, or anemic dogs that are synthesizing hemoglobin. The intake needed for regeneration of hemoglobin is less than 0.66 mg absorbable iron per kilogram of body weight (Ruegamer *et al.*, 1946). If a large amount of the iron came from soluble inorganic salts, the allowance might be reduced, but reduction seems inadvisable in view of lack of information about the effect of other dietary constituents on iron absorption. McCance and Widdowson (1944) found that many substances (e.g., phosphates and phytates) depress utilization of dietary iron. Likewise, iron from insoluble iron salts and certain slightly soluble sources is poorly utilized. The allowance suggested, 1.32 mg/kg of body weight per day, is slightly in excess of that provided by the widely used mineral mixture suggested by Phillips and Hart (1935). However, the reports of satisfactory nutrition in dogs fed the Phillips and Hart mixture have been based on refined diets rather than on mixtures of natural foodstuffs, which may contain interfering substances. There are variations in the efficiency with which various species utilize iron from iron-containing salts. Ferric ammonium citrate and ferrous sulfate are highly effective for preventing anemia in a number of species (Wintrobe, 1967; Fritz *et al.*, 1970).

Usually 5–10 percent of the oral iron intake is absorbed (Stewart and Gambino, 1961; Talwar *et al.*, 1961; Pollack *et al.*, 1963, 1964), but many factors influence absorption, including the chemical form of the iron (Brown, 1963; Fritz *et al.*, 1970), associated food proteins (Fitch *et al.*, 1964), mineral balance of the diet, hormone balance (Cline and Berlin, 1963), freedom from intestinal abscesses (Hahn *et al.*, 1946), vitamin stores, severity of anemia (Koepke and Stewart, 1964a, b), and diurnal variations (Goldstone *et al.*, 1962).

The gastric juice from anemic dogs contains a substance that increases the absorption of iron from the gastrointestinal tract. When the gastric juices from anemic dogs and iron were given to normal dogs, the absorption of iron was significantly increased (Koepke and Stewart, 1964a, b; Arriaga de la Cabada *et al.*, 1969).

The iron of wheat bran has been shown to be as available as that of ferric pyrophosphate, but that of spinach is less than half as available (Frost *et al.*, 1940). These findings conform with the relative availability of the iron in those three sources when fed to rats and suggest that availability for the rat may be used as a guide for dogs. Elvehjem *et al.* (1933, 1934) and Sherman *et al.* (1934) have shown the iron of inorganic salts, liver, heart, muscle, and soybeans to be readily available (50 percent or more utilized) while the utilization from oysters, alfalfa, spinach, blood, wheat, oats, and yeast was lower (25 percent utilized). Recent evidence (Bannerman, 1965) has demonstrated that dogs utilize iron from porphyrin compounds, such as hemoglobin and myoglobin, more efficiently than other species. In this respect, they are similar to man. Dogs consuming large amounts of meat and bone may require slightly less supplementation of their diets with inorganic iron salts (Udall and McCay, 1953; Bannerman, 1965), but additional data are needed to verify such a conclusion.

Iron and copper are essential for preventing anemia.* Most of the iron in a dog's body is in the respiratory

* Linton (1934), Phillips and Hart (1935), Potter *et al.* (1938), Frost *et al.* (1940), McCance and Widdowson (1944), Hahn *et al.* (1946), McCay (1949), Goldstone *et al.* (1962), Murray *et al.* (1962), Moore (1963), Pollack *et al.* (1963, 1964), Koepke and Stewart (1964a, b), Arriaga de la Cabada *et al.* (1969).

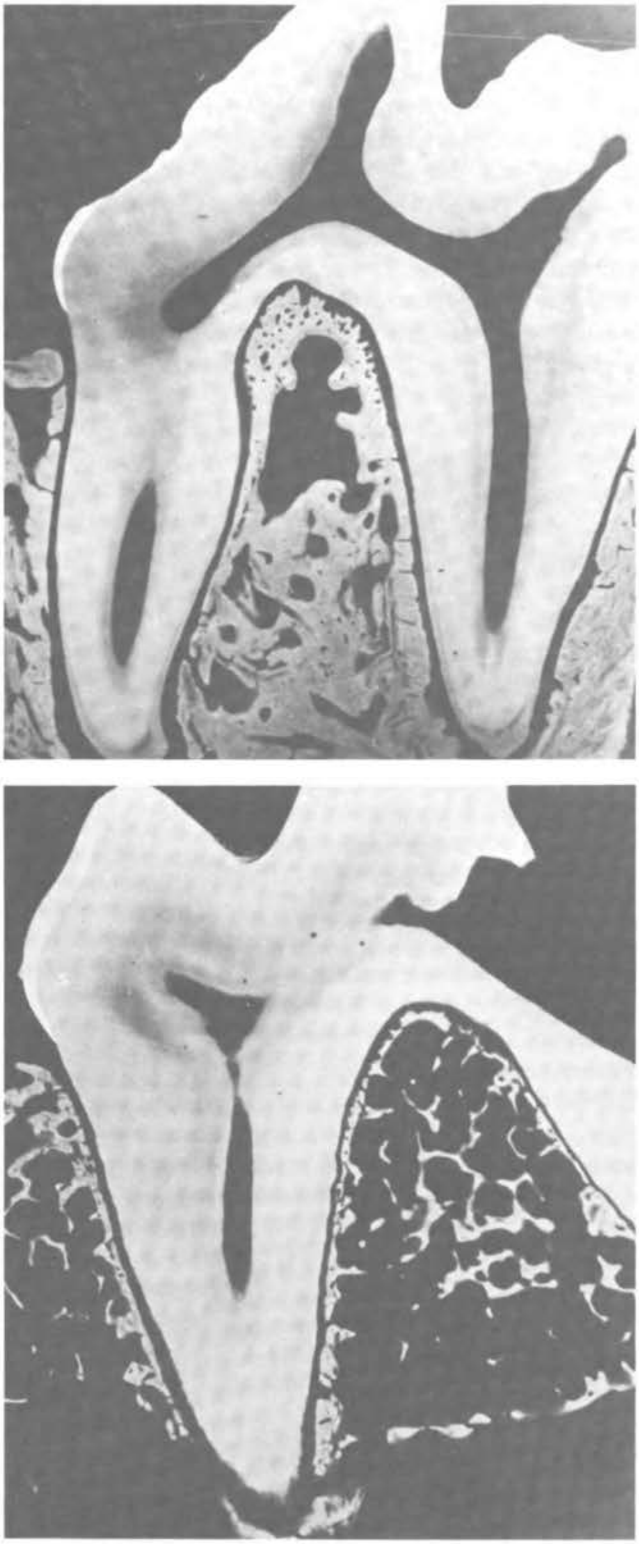

FIGURE 3 Calcium and phosphorus imbalance as revealed in microradiograms of ground sections of the first mandibular molars of littermate Beagle dogs. *Above:* The dog was fed 0.54 percent of calcium and 0.42 percent of phosphorus for 12 months beginning at 1 year of age. *Below:* The dog was fed 0.12 percent of calcium and 1.20 percent of phosphorus for the same period beginning at the same age. Note difference in alveolar bone.

Courtesy of Lennart Krook, Cornell University.

pigments (hemoglobin and myoglobin) and in various enzymes. The characteristic anemia associated with an iron deficiency is of a hypochromic, microcytic type. However, hypochromic anemias may also occur when the total iron content of the body is normal, indicating that factors other than total body iron are also involved (Moore, 1963).

Frost *et al.* (1940) and Linton (1934) reported that copper was necessary for incorporating iron into hemoglobin. Without copper, iron was absorbed but hemoglobin was not formed efficiently. Two milligrams of copper per day given dogs weighing up to 13 kg, met the requirements of these dogs for growth and regeneration of hemoglobin, and 0.16 mg/kg of body weight per day has been tentatively accepted as the recommended allowance.

Signs of Deficiency Iron is a part of the hemoglobin molecule and is essential for oxygen transport. Thus, iron-deficient dogs exhibit anemia and tissue anoxia. The mean corpuscular hemoglobin concentration and mean corpuscular volume are decreased, and the anemia may be characterized as microcytic and hypochromic. While not all hypochromic anemias are attributable to iron deficiency (Moore, 1963), if iron deficiency is responsible, serum iron will be depressed and the erythropoietic system of an affected dog will respond quickly to iron-dextran administered orally, intramuscularly, or intraperitoneally.

Dogs on low iron, low protein diets are severely affected by hookworm infestations, and, when returned to a normal iron and protein intake, they appear to develop some resistance against hookworms (Foster and Cort, 1932).

Toxicity Iron toxicity in dogs has been studied extensively (Cibis *et al.*, 1957; Brown *et al.*, 1959; Bronson and Sisson, 1960; D'Arcy and Howard, 1962a, b) and is associated with anorexia, weight loss, and decreased serum albumin concentration. Although some dogs have been fed as long as 18 months on diets containing 1-percent iron oxide, other salts have proved toxic at very low levels (D'Arcy and Howard, 1962a). Ferrous sulfate administered orally produced gastrointestinal damage when fed in a dosage of 0.012 g/kg of body weight. Ferrous carbonate did not produce such changes at 1.5 g/kg of body weight, but did so at 3 g/kg.

Cobalt

Frost *et al.* (1939) reported that 0.1 mg of cobalt per day stimulated hemoglobin production. One-half milligram per day, along with 2 mg of copper and 10 mg of iron, used by Frost *et al.* (1940), apparently provided for more efficient conversion of iron to hemoglobin than did iron and copper alone. This research was conducted before vitamin B_{12} was discovered. If the diet were inadequate in vitamin B_{12}, supplemental cobalt may have permitted intestinal microbial synthesis of this cobalt-containing vitamin. Frost *et al.* (1939) also reported that 4 mg of cobalt per day produced polycythemia. Stanley *et al.* (1946) injected 2.4–10 mg of cobalt per kilogram of body weight into rats for 8 months, producing polycythemia and increased blood volume and erythrocyte volume with all dosages. They concluded, however, that these results did not indicate serious toxicity.

The above data were derived before the isolation of vitamin B_{12}, which contains cobalt. With ample vitamin B_{12}, a deficiency of cobalt has not been demonstrated. Thus, no cobalt requirement is shown in Tables 1 and 2.

Potassium

Most of the diets prepared from the usual pet food formula ingredients contain enough sodium, potassium, chlorine, iodine, and most of the other trace minerals, to meet requirements. Ruegamer *et al.* (1946) fed purified low-potassium diets (5 kcal ME per g) to dogs and produced poor growth, restlessness, and paralysis of the neck and the forepart of the body. Administration of a single 3-gram dose of potassium chloride by capsule and inclusion of the salt in the diet at a 0.6-percent level relieved these conditions, and permitted normal growth. This amount, equivalent to that obtained from a diet containing 0.32-percent potassium, provided about 70 mg of potassium per kilogram of body weight daily when the diet was fed at the rate of 22 g/kg of body weight.

The rat and dog differ in their potassium needs (Burnell and Dawson, 1970). Dogs can be severely depleted of potassium in 30 days and repleted in 14 days (Abbrecht, 1972). An allowance for growth of 264 mg of potassium per kilogram of body weight per day is suggested as a minimum. This amount is considerably less than the 530 mg/kg provided by the salt mixture formulated by Phillips and Hart (1935), but that mixture was intended to provide generous amounts, and no data regarding potassium requirements were available when it was formulated.

Serrano *et al.* (1964) found that feeding low-potassium diets to pregnant bitches did not affect litter size or birth weight of the puppies, although the bitches had reduced concentrations of blood potassium. In contrast to their dams, the puppies had normal blood and muscle electrolyte concentrations. The potassium content of the diets was not reported.

Signs of deficiency are poor growth, restlessness, muscular paralysis, a tendency to dehydration, and lesions of the heart and kidney.

Sodium and Chlorine

Sodium and chlorine are essential for normal physiological performance and must be provided by ingredients of the diet or by sodium chloride supplements. Inadequate data are available to set a minimal requirement for sodium and chlorine. Some natural feedstuffs may contain enough sodium and chlorine to meet normal requirements, and some water supplies contain ample sodium to meet requirements. However, salt (NaCl) is generally included as about 1 percent of the air-dry diet.

Humans who have inadequate sodium chloride in their diets become fatigued easily. McCance (1936) and McCance and Widdowson (1944) have observed similar fatigue in dogs and decreased utilization of protein in man and in dogs with prolonged sodium chloride deficiency.

In experiments with dogs fed diets containing 2-percent added sodium chloride, McCay (1949) observed greater-than-normal water intake but normal health.

Dogs fed less than 23 mg of sodium per kilogram of body weight per day showed changes in concentrations of blood-pressure regulating hormones in 3 days, whereas dogs fed 80 mg/kg did not show these changes (Bunag *et al.*, 1966; Ganong and Boreyzka, 1967; Brubacher and Vander, 1968).

One percent of sodium chloride in the total dry-type diet will supply normal needs and is not excessive for normal dogs. This amount, equivalent to about 242 mg of sodium chloride (or 95 mg of sodium and 147 mg of chlorine) per kilogram of body weight per day, has been designated as an appropriate allowance, but probably exceeds the minimum requirement.

Signs of deficiency are fatigue, exhaustion, inability to maintain water balance, decreased water intake, retarded growth, dryness of skin, and loss of hair.

Iodine

Dogs require small amounts of iodine for prevention of goiter (Marine and Lenhart, 1909). Salt mixtures supplying 4.5 mg of iodine per kilogram of diet have proved satisfactory (Phillips and Hart, 1935). Iodized salt (0.008-percent iodine) is generally considered effective in preventing iodine deficiency, and incorporation in dry-type diets of 1-percent iodized salt in addition to the iodine in the diet ingredients, should meet iodine requirements.

The level of iodine in the diet influences thyroidal uptake in the animal, and uptake is influenced by lymphocytic thyroiditis (Fritz *et al.*, 1970). The full cycle of thyroid gland accommodation to limited dietary iodine has been demonstrated in experimental animals (Norris *et al.*, 1970). Purebred Beagles (11-month-olds) previously maintained on a dog food that allowed each animal more than 500 μg of iodine per day were fed a semisynthetic diet that provided 50–75 μg of iodine per day. The uptake and release of ^{131}I by the thyroid glands were measured periodically for 651 days. During the first 268 days of restricted iodide intake, the thyroid glands became hyperplastic and hypertrophic. Hyperplasia and hypertrophy were correlated with a large increase in thyroidal uptake of test doses of ^{131}I and also with more rapid loss of ^{131}I from the gland after the point of maximum uptake. After 368 days of restricted iodide intake, the thyroid glands were involuted and had an essentially normal histological appearance. Thyroidal uptake of ^{131}I remained high, but the subsequent rate of loss of ^{131}I was drastically reduced. This correlated with the return of thyroglobulin to the gland.

Practical experience has shown that the requirement for maintenance is met by 34 μg of iodine per kilogram of body weight per day. Stable but biologically active iodine sources, such as pentacalcium orthoperiodate or calcium iodate, should be used.

Goiter is the main sign of iodine deficiency. Cretinism in dogs has been reported in localities where goiter is endemic. Myxedema appears in the skin, and skeletal deformities lead to a short, broad nose; coarse, heavy extremities; a short body; and delayed shedding of deciduous teeth (Dammrich, 1963). Other signs of deficiency are hairlessness, dullness, apathy, drowsiness, and timidity.

Excessive amounts of iodine may be toxic.

Zinc

Robertson and Burns (1963) produced a zinc-deficiency syndrome in dogs by adding 2 percent of calcium carbonate to a diet containing 0.3-percent calcium and 33 mg/kg of zinc. Differences in weight gain were apparent after 3 months of feeding, and skin lesions appeared on the abdomen and extremities. The syndrome was characterized by marked emaciation, emesis, conjunctivitis, keratitis, general debility, and retardation of growth. There were calcium deposits in the renal pelvis, and renal damage was noted. All changes could be corrected with additional zinc.

Radiozinc uptake by subcellular fractions were compared in normal and infarcted myocardia in dogs. Increased radiozinc uptake in the infarctions suggested that zinc was mobilized to participate in tissue repair (Baxter *et al.*, 1970).

Montgomery *et al.* (1943) measured zinc excretion from dogs that had been injected with ^{65}Zn; 6.5 percent of the dose was excreted in pancreatic juice within 5 days.

For dogs consuming a high-cereal diet with a normal calcium concentration, 1.1 mg of zinc per kilogram of body weight per day will meet requirements for maintenance, based on work with dogs and other species. Excessive dietary calcium concentrations in a cereal diet may increase zinc requirements further; zinc requirements on a high-meat diet may be lower.

Signs of zinc deficiency include alopecia, hyperkeratinization and acanthosis, disturbance in growth, anorexia, and emaciation.

Magnesium

Requirements Bunce *et al.* (1962a, b) obtained evidence that the magnesium requirement of puppies varied with the dietary level of phosphorus. On a 0.6-percent calcium and 0.4-percent phosphorus diet, the magnesium requirement of puppies was 140 mg/kg of diet on a dry basis and that of mature dogs was between 80 and 180 mg/kg.

Similar findings were reported by Vitale *et al.* (1961), who fed magnesium-deficient diets to dogs. The changes that occurred as a result of feeding these diets are described under "Signs of Deficiency," below. None of these changes occurred when the basal purified diet contained 960 mg of magnesium and 5000 mg of potassium per kilogram. This concentration of magnesium is considerably higher than that recommended by Bunce *et al.* (1962a) and presumably was used to ensure adequate intake.

Convulsive seizures and alterations in sodium and potassium transport were observed by Kahil *et al.* (1966) after feeding a magnesium-deficient diet. These signs were not observed in animals receiving 16 mg of magnesium as anhydrous magnesium chloride per kilogram of body weight per day.

Morris (1963) found that when weanling puppies were fed diets containing 30, 100, or 320 mg/kg magnesium, the calcium concentrations found in the aorta were 8320, 5450 or 980 mg/kg (dry basis), respectively.

The recommended magnesium allowance, based on the above research and research with other species, is 0.04 percent of the diet on a dry basis.

Signs of Deficiency Bunce *et al.* (1962a), conducted studies in which puppies were fed a magnesium-deficient diet containing 0.6-percent calcium, 0.4-percent phosphorus, and 8-percent fat. The investigators observed anorexia, decreased weight gain, and muscular weakness, which included pronounced relaxation of muscles and tendons of the legs. The aortas of these animals contained extensive mineralized lesions, primarily calcium and phosphorus deposits. Blood serum magnesium and calcium concentrations were depressed and inorganic phosphorus elevated. A much longer depletion period was required to demonstrate magnesium deficiency in mature dogs than in younger dogs. In mature dogs there was a loss in body weight and a depression in serum magnesium, but there were no changes in serum calcium and phosphorus.

Vitale *et al.* (1961) recorded electrocardiographic changes in puppies fed magnesium-deficient diets that were similar to those seen in hyperkalemia. Subsequent studies in dogs 4–6 months old demonstrated a relationship between magnesium deficiency and potassium deficiency. Hypokalemia and marked electrocardiographic changes were recorded in two dogs that received a magnesium-deficient diet for 9 months; the changes were similar to those observed in dogs deficient in both magnesium and potassium.

Kahil *et al.* (1966) fed a purified diet containing 0–5 mg/kg of magnesium to puppies having an initial age of 7–9 weeks. After 3 weeks of feeding, the investigators observed anorexia, vomiting, decreased weight gain, and hyperextension of the front legs. By 4–6 weeks, all dogs on the deficient diet showed irritability, ataxia of hind legs, convulsive seizures, and alterations in sodium and potassium transport. (See Figure 4.)

Manganese

Little is known about the requirements of dogs for manganese. It is known to play a role in catalyzing several metabolic reactions; hence, it is common practice to include small amounts in the diets of all animals. The concentrations used in the salt mixture of Phillips and Hart (1935) seem adequate. Major feed ingredients may contribute considerable manganese, and it may be unnecessary to add manganese to practical diets. Based on practical experience, 0.11 mg/kg of body weight per day will meet adult requirements.

Selenium

In a preliminary 10-week study with a litter of four Beagles, the addition of 0.5 mg/kg of selenium as sodium selenite to a basal semisynthetic selenium- and vitamin E-deficient diet resulted in protection against the development of fatal skeletal and cardiac myopathy

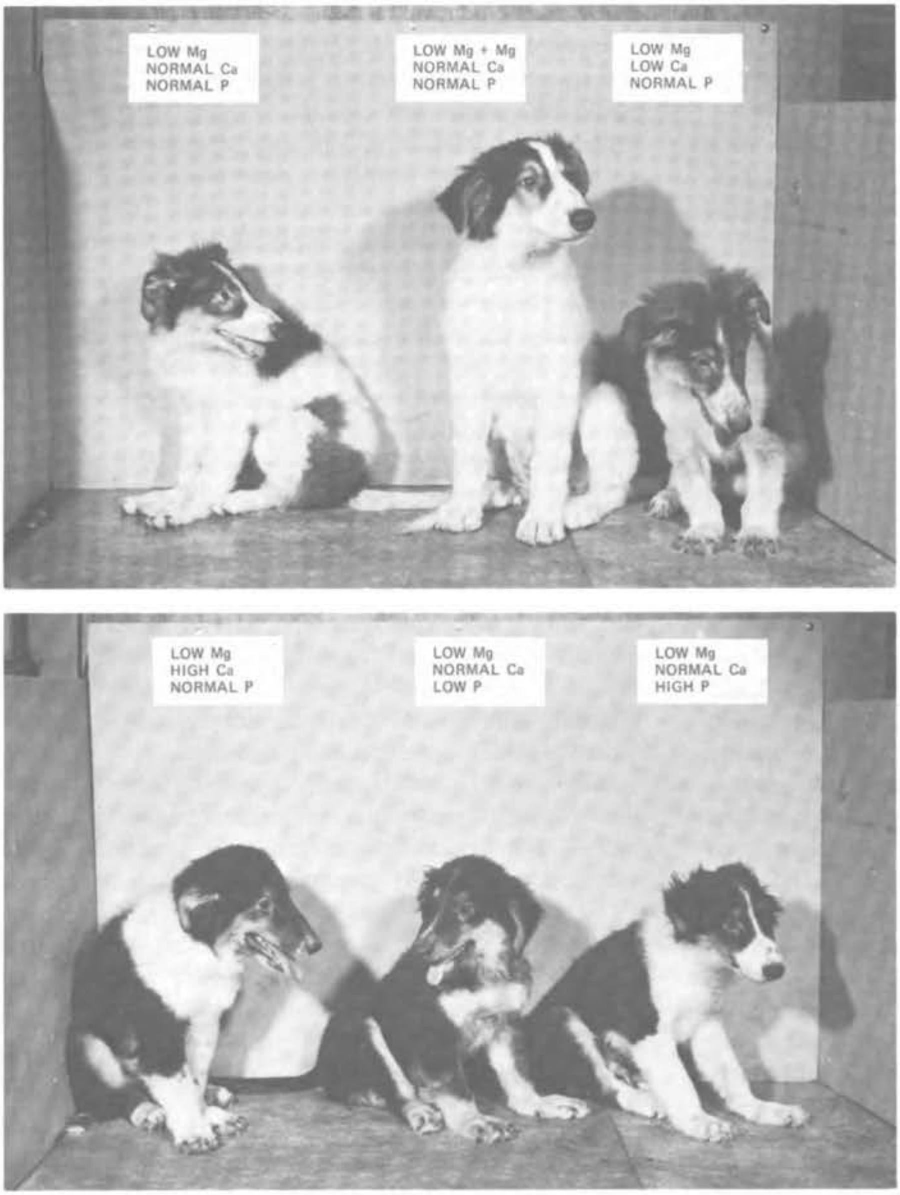

FIGURE 4 Six littermates fed diets varying in calcium, phosphorus, and magnesium. The dog in the center (top photograph) was fed a magnesium-supplemented basal ration. The other dogs were fed low-magnesium basal rations. The photographs were taken after 10 weeks of experiment. *Courtesy of G. E. Bunce, Virginia Polytechnic Institute, Blacksburg. Reprinted with permission from the* Journal of Nutrition, *Vol. 76 (1962), American Institute of Nutrition.*

observed in the two dogs not supplemented with selenium (Van Vleet, 1972). Both unsupplemented dogs died and exhibited at necropsy intestinal lipofuscinosis, common in vitamin E deficiency. This also occurred in the dogs fed selenium, indicating that the vitamin E requirement cannot be met by selenium. Based on other species, practical dry-type diets should probably supply a minimum of 0.1 mg/kg selenium.

Fluorine

Experimental evidence shows that Beagles do not deposit more mineral in their bone when a low-calcium, high-phosphorus diet is supplemented with fluorine (Krook, 1969; Henrikson *et al.*, 1970; Krook *et al.*, 1971).

Fluorine, fed as sodium fluoride at 0.45–4.5 mg/kg of body weight pet day, comparable with the quantity found in some drinking water, caused mottling of the tooth enamel during the period of calcification of permanent teeth in dogs (Biester *et al.*, 1936).

Andreeva (1959) reported that the addition of fluorine at 20 mg/kg of body weight daily for 92 days to the diet of month-old pups altered serum calcium and inorganic and organic phosphorus concentrations significantly. Fluoride–chloride therapy has been reported to promote thicker trabeculae and callus formation following fractures in dogs (De Gubareff and Platt, 1969). Feeding 200 or 250 ppm of fluorine in a diet deficient in magnesium prevented aortic calcification normally found in magnesium deficiency (Bunce *et al.*, 1962; Chiemchaisri and Phillips, 1963).

A minimum requirement for fluorine has not been established for dogs.

Molybdenum, Tin, Silicon, Nickel, Vanadium, and Chromium

The dietary requirements of the dog for these elements have not been established.

VITAMINS

Certain vitamins have been recognized as essential nutrients for dogs for over 50 years. Despite this long history, precise quantitative requirements have not been established for each vitamin. The recommendations made in Tables 1 and 2 are designed to provide levels that are reasonable based on research with dogs and other species and that have proven satisfactory in practice. The concentrations in Table 1 may be related to daily requirements in Table 2 by assuming 22 g of dry matter consumption per kg of body weight per day by adult dogs for maintenance and by doubling this amount for growing puppies. Although the vitamin requirements for gestation, lactation, and muscular effort have not been well defined, these needs are generally related to energy intake. As energy intakes increase in relation to the extra demands of milk production or exercise, daily intakes of vitamins will also increase. The nutrient requirements in Table 1 have been set to meet the needs of the entire life cycle of the dog. Since several vitamins are rather unstable, and their destruction may be promoted by light, heat, oxidation, moisture, rancidity, or certain mineral elements, sufficient amounts should be provided to ensure that the recommended concentrations will be present when the diet is consumed. Just as important is recognition that markedly excessive intakes of several vitamins may be harmful to dogs, and that the margin of safety between minimum requirements and toxic levels of certain vitamins is relatively small.

Vitamin A

Requirements Dietary requirements for vitamin A were studied by Frohring (1935, 1937a). By feeding a vitamin A-deficient diet to Beagle puppies, it was established that approximately 100 IU of vitamin A per kilogram of body weight were lost from the liver each day. The minimum curative dose that effected a definite increase in weight was 200 IU (in the form of β-carotene) per kilogram of body weight per day. Crimm and Short (1937), using a similar vitamin A depletion technique, estimated that daily vitamin A requirements of adult dogs were 22–47 IU/kg of body weight. Bradfield and Smith (1938) fed 200, 400, 1000 or 2000 IU of vitamin A from cod liver oil per kilogram of body weight per day to growing puppies and measured weight gain and liver vitamin A concentration. To compare the vitamin A activity of carotene sources, other puppies received 200 IU of carotene in oil or from carrots per kilogram of body weight per day. While increasing dietary intakes of vitamin A resulted in increasing liver vitamin A levels, 200 IU were adequate to produce maximum gains and slight liver vitamin A storage. At this level, cod liver oil and carotene in oil or from carrots appeared to be equally well utilized as sources of vitamin A activity, confirming Turner's (1934) earlier observation that dietary carotene (from carrots) may be converted to vitamin A, which is then stored in the liver.

Vitamin A has been used pharmacologically for certain diseases in dogs presumably receiving adequate dietary levels of this nutrient. Wakerlin *et al.* (1942) reported marked reductions in blood pressure in dogs with experimental renal hypertension when given 200,000 IU daily *per os* for 3 months followed by 400,000 IU daily for an additional 3 months. In dogs with experimental atherosclerosis, Krause and Brown (1967) found that, while atherosclerotic dogs did not show impaired glucose tolerance, oral daily supplements of 5000 IU of vitamin A increased the rate of glucose utilization. Martin (1971) found that corneal epithelial healing rate was not improved by a single oral dose of 100,000 IU of vitamin A plus 25,000 IU administered topically four times a day as compared to untreated controls, nor did vitamin A counteract corticosteroid inhibition of epithelial healing.

Daily vitamin A requirements should be met by 110 IU/kg of body weight for adult maintenance and 220 IU/kg of body weight for growing puppies. These amounts will be provided by a dietary concentration (dry basis) of 5000 IU/kg.

Signs of Deficiency Vitamin A deficiency in the dog was among the first of the vitamin deficiencies to be recognized. Steenbock *et al.* (1921) reported that dogs deprived of fat-soluble vitamins developed an "ophthalmia". These and other workers (Stimson and Hedley, 1933; Crimm and Short, 1937; Mellanby, 1938; Russell and Morris, 1939; Singh *et al.*, 1965) have observed the following deficiency signs: anorexia, weight loss, ataxia, xerophthalmia, conjunctivitis, corneal opacity and ulceration, skin lesions, metaplasia of the bronchiolar epithelium, pneumonitis, and increased susceptibility to infection with associated changes in the blood leukocyte differential count. Faulty bone remodeling in the young dog, with a failure of the neural foramina to enlarge, resulted in pressure-induced degeneration of nerves and impaired nerve functioning. Mellanby (1938) established that such damage to the cochlear and vestibular divisions of the eighth cranial nerve, plus a serous labyrinthitis, may induce deafness. Similar damage may also affect function of the optic and trigeminal nerves.

Hypervitaminosis A Maddock *et al.* (1949), using 2-month-old Greyhound puppies orally administered 300,000 IU of vitamin A per kilogram of body weight each day except Sunday. Anorexia was first noted on the thirtieth day. Weight gains were 60–70 percent of controls for the first 53 days, but at this time weight declined precipitously. After 53 days, a variety of clinical signs rapidly appeared. Hyperesthesia of the skin and extreme tenderness of the extremities were evident. The puppies were unwilling to stand, although no fractures were noted. The long bone epiphyseal cartilage was markedly narrower; cortices of the femur, tibia, radius, and ulna were less dense and thinner. Remodeling processes were greatly accelerated, and hemorrhage was common in these areas. Moderate exophthalmos was evident. Degenerative lesions of the media were found in arteries and veins of the myocardium, gall bladder, and urinary bladder. Serum vitamin A levels reached 8380–20,400 IU/100 ml, compared to 660–1182 IU in the controls. These values may be compared with those reported by Keane *et al.* (1947) in 21 healthy dogs examined at a New Jersey animal hospital. The range of plasma vitamin A concentrations was 180–1800 IU/100 ml, with a mean of 564 IU.

Wiersig and Swenson (1967) found that daily oral administration of 125,000 IU of vitamin A per kilogram of body weight to Beagle bitches on gestation days 17–22 produced cleft palate in the puppies.

Hendricks *et al.* (1947) found no adverse effects due to the continuous feeding of 10,000 IU vitamin A per kilogram of body weight to weaned Cocker Spaniel puppies for 8–10 months.

Vitamin D

Although vitamin D has long been recognized as a vital factor in calcium and phosphorus metabolism of the dog, recent discoveries (Omdahl and DeLuca, 1973), e.g., that the vitamin undergoes a series of metabolic conversions before becoming physiologically active, add a new dimension to our knowledge. It would appear that 25-hydroxylation in the liver, followed by 1-hydroxylation in the kidney, results in a 1,25-dihydroxyvitamin D that promotes intestinal calcium transport and bone mineral mobilization. Biological synthesis of this metabolite is induced by low plasma calcium levels, an effect mediated through parathormone. A second metabolite, which is synthesized at normal plasma calcium levels and seems to function primarily in the promotion of intestinal calcium transport, is 1,24,25-trihydroxyvitamin D (Lam *et al.*, 1973). Most vitamin D research has been done with cholecalciferol (vitamin D_3), rather than ergocalciferol (vitamin D_2), and with rats or chickens, rather than dogs. Nevertheless, it is probable that these metabolic interconversions also occur in the dog and may be related to production of a calcium-binding protein that participates in calcium absorption and transport (Wasserman, 1970).

Requirements Requirements for vitamin D are dependent on dietary concentrations of calcium and phosphorus, the dietary calcium–phosphorus ratio, physiological stage of development, and perhaps sex and breed. Kozelka *et al.* (1933) found that Collie puppies were protected from rickets by 1–1.3 IU of vitamin D (irradiated ergosterol) per kilogram of body weight per day. Arnold and Elvehjem (1939) found calcification to be normal in a growing Airedale puppy receiving 13 IU or less of vitamin D per kilogram of body weight per day. Further studies with Great Dane puppies receiving a 1.39-percent calcium and 1.05-percent phosphorus (Ca:P = 1.32) diet and 12 IU or less of vitamin D per kilogram of body weight per day, showed that growth and bone mineralization were normal. When part-Great Dane puppies were fed diets with a calcium–phosphorus ratio of either 1.2 or 2.0, providing 12 IU or less of vitamin D per kilogram of body weight per day, the puppy receiving a calcium–phosphorus ratio of 1.2 was normal throughout the 125-day trial; the puppy receiving a calcium–phosphorus ratio of 2.0 became severely rachitic. Fleischmann Laboratories (1940) reported that 28 IU of vitamin D per kilogram of body weight daily was sufficient for Fox Terriers when using a dietary calcium–phosphorus ratio of 2.1. However, even with 270 IU per kilogram of body weight per day, Collies and Great Danes showed x-ray evidence of rickets. Michaud and Elvehjem (1944) concluded that, with a dietary calcium–phosphorus ratio of 1.2, daily intakes of 10–20 IU of vitamin D per kilogram of body weight were adequate—even for large breeds.

Wheatley and Sher (1961), in an analysis of the lipids of dog skin, were unable to isolate 7-dehydrocholesterol (provitamin D_3) despite practical experience (McCay, 1949) that sunlight exposure minimized problems with rickets, indicating probable conversion of the vitamin D precursor upon exposure to ultraviolet light. Arnold and Elvehjem (1939) have concluded that dogs use orally administered ergocalciferol (vitamin D_2) or cholecalciferol (vitamin D_3) equally well.

When the dietary calcium–phosphorus ratio is 1.2, daily vitamin D requirements should be met by 11 IU per kilogram of body weight for adult maintenance and 22 IU per kilogram of body weight for growing puppies. These amounts will be provided by a dietary concentration (dry basis) of 500 IU/kg.

Signs of Deficiency Vitamin D deficiency signs are frequently confounded by a simultaneous deficiency or imbalance of calcium and phosphorus. Campbell and Douglas (1965) fed a 0.5-percent calcium and 0.3-percent phosphorus diet, with no supplemental vitamin D, to puppies for 15 weeks without signs of rickets or osteoporosis. Likewise, plasma calcium and inorganic phosphorus concentrations, plasma alkaline phosphatase activity, and calcium and phosphorus retention were normal. When the diet contained 0.08–0.10-percent calcium and 0.13–0.15-percent phosphorus, and no supplemental vitamin D, rickets complicated by osteoporosis was observed. When this diet plus a daily supplement of 100 IU of vitamin D per kilogram of body weight was supplied, osteoporosis was evident but rachitic changes were only very slight.

Hypervitaminosis D Morgan and Shimotori (1943) administered a single oral dose of 20,000 IU of vitamin D—from tuna liver oil, irradiated ergosterol, or activated animal sterol—per kilogram of body weight to three Cocker Spaniel puppies that had been depleted of vitamin D for 2 months after weaning. They were observed until they were 12–14 months old. No deleterious effects on growth, appetite, or general behavior were noted. There was a transient hypercalcemia apparent in the first post-dosing blood sample taken at 4 hours. Vitamin D was measurable in the blood for 100 days to 5 months post-dosing. At 12–14 months of age, these dogs were given a second oral dose of 200,000 IU of vitamin D (irradiated ergosterol or animal sterol) per kilogram of body weight. Vomiting and diarrhea were observed within 3 days, along with lassitude, weakness, rapid respiration, excessive lacrymation, and anorexia. Serum calcium concentrations first declined and then rose, together with inorganic phosphorus levels, within the first 12 hours. After 3 days the dogs were killed, and tissue vitamin D concentrations were 1.6–5 IU/g of fresh tissue in the liver, 3–8 IU/g in the kidney and 3–5 IU/g in the heart.

Morgan *et al.* (1947) administered a single oral dose of 314,000–530,000 IU of vitamin D as irradiated ergosterol per kilogram of body weight to 4–5-week-old puppies. All exhibited anorexia, polyuria, bloody diarrhea, polydipsia, and prostration. Three were dead within 2 weeks and a fourth was moribund in 5 weeks. Extensive calcification was found in the lungs of these dogs, and moderate calcification in the hearts and kidneys. In the dogs that survived, malocclusion, pitting, irregular placement, and poor development of the teeth was seen.

Hendricks *et al.* (1947) fed 10,000 IU of vitamin D daily per kilogram of body weight to weaned Cocker Spaniel puppies. Irradiated ergosterol, irradiated animal sterol, or tuna liver oil served as the source. Treatment was continued for 8–10 months. Anorexia developed, growth was retarded, serum calcium was variably increased, jaws and teeth were deformed, and soft tissues were calcified—particularly the lungs, kidneys, and stomach.

Vitamin E

Requirements While the need for vitamia E in dog diets was demonstrated by Anderson *et al.* (1939), the interrelationship with dietary selenium concentrations has only recently been studied (Van Vleet, 1972). Since selenium was identified as an essential nutrient in 1957 (Schwarz and Foltz, 1957), few of the vitamin E studies with dogs have taken this factor into account. Both nutrients are important in protecting cell membranes against peroxidation and the destructive effects of free radicals. Vitamin E serves as a free radical chain-breaker, and selenium-containing glutathione peroxidase reduces the peroxides that are formed (Chow and Tappel, 1974). Dietary requirements for vitamin E are also closely related to the dietary concentration of polyunsaturated fatty acids (PUFA) (Hayes *et al.*, 1969). Harris and Embree (1963) have proposed a dietary α-tocopherol–PUFA ratio (mg/g) of 0.6 as a minimum to protect against PUFA oxidation. It is noteworthy that American human diets have an average α-tocopherol–PUFA ratio of 0.43, without evidence of vitamin E deficiency (Bieri and Evarts, 1973).

Elvehjem *et al.* (1944) reported that 0.62 mg (0.68 IU) of α-tocopherol per kilogram of body weight per day would not sustain normal reproduction in Fox Terriers fed unsweetened, irradiated evaporated milk, while 1 mg (1.1 IU) would. However, one pup out of four from a bitch receiving the higher level of vitamin E exhibited slight muscular dystrophy. Kaspar and Lombard (1963) fed a semipurified diet containing 10-percent cottonseed oil and 100 mg *dl*-α-tocopheryl acetate per kilogram to a Beagle bitch from 4 weeks before breeding through lactation, and to the pups weaned at 56 days. Myodegeneration was noted in the pups at 62 days of age, and one pup died at 68 days with gross and histological evidence of vitamin E deficiency. Three pups were treated orally with 25 mg *dl*-α-tocopheryl acetate daily (plus general vitamin therapy), and recovery from myodegeneration was considered clinically complete in 10 days. The above researchers did not report the selenium concentrations of their basal diets, and, as a consequence, inadequate research data are available to set a minimum vitamin E requirement. Schaefer (1954) suggested feeding 20 mg of tocopherol per kilogram of dry diet.

Based on research with other species, and assuming a dry diet containing 1-percent linoleic and 0.1 mg/kg selenium, the recommended daily allowance is 1.1 IU vitamin E per kilogram of body weight for adult maintenance and 2.2 IU/kg body weight for growth. These levels would be provided by 50 IU/kg dry diet (one IU = 1 mg *dl*-α-tocopheryl acetate = 0.67 mg *d*-α-tocopherol). If dietary PUFA levels are increased, it is suggested that an α-tocopherol–PUFA ratio of at least 0.5 be maintained. Rancin fats should be avoided because of their particular destructiveness to tocopherols.

Signs of Deficiency A number of authors (Anderson *et al.*, 1939, 1940; Brinkhous and Warner, 1941; Elvehjem *et al.*, 1944; Kaspar and Lombard, 1963; Cordes and Mosher, 1966; Van Kruiningen, 1967; Hayes *et al.*, 1969, 1970) have published signs of presumed vitamin E deficiency. Particularly prominent were dystrophy of skeletal muscle and associated muscle weakness, degeneration of testicular germinal epithelium and failure of spermatogenesis, gestation failure, weak and dead pups, brown pigmentation (lipofuscinosis) of the intestinal muscularis, decreased plasma tocopherol concentrations, increased dialuric acid hemolysis of erythrocytes, and elevated plasma creatine phosphokinase values.

Hypervitaminosis E No deleterious effects were reported when 11 mg (15 IU) of *d*-α-tocopheryl acetate per kilogram of body weight were fed daily to weaned Beagle puppies for 15 weeks (Hayes *et al.*, 1969). It should be noted, however, that March *et al.* (1973), working with chicks, found that thyroid activity was depressed by 220 IU of vitamin E per kilogram of diet, and 2200 IU per kilogram of diet decreased the respiration rate of skeletal muscle mitochondria. This higher level also induced reticulocytosis, lowered hematocrit values, and prolonged clotting times—the latter reversed by vitamin K injection. The above findings suggest that excess vitamin E, like the other fat-soluble vitamins, must be considered potentially toxic.

Vitamin K

Requirements The metabolic need for vitamin K has been well established in the dog. Anderson and Barnhart (1964) have shown that vitamin K_1 (2-methyl-3-phytyl-1,4-naphthoquinone) stimulates prothrombin synthesis by the liver parenchymal cells in dogs made hypoprothrombinemic by coumarin compounds. Duello and Matschiner (1971) have isolated 19 vitamin K analogs in dog liver and suggested that most were absorbed from the intestine and were not tissue metabolites. A bacterial origin for many of these vitamins was considered likely.

The need for supplemental vitamin K has been demonstrated in adult dogs following diversion of bile from the intestine by means of a cholecystonephrostomy (Quick *et al.*, 1954). Vitamin K absorption from both diet and intestinal bacterial synthesis was apparently reduced, and 0.5 μg of vitamin K_1 per kilogram of body weight injected intravenously each day sustained normal plasma prothrombin levels. Using the same surgical technique with puppies, Quick *et al.* (1962) concluded that daily intravenous injections of 10–15 μg of vitamin K_1 per kilogram of body weight were necessary to sustain normal plasma prothrombin levels during active growth, with a decline in requirement to 5 μg or less per kilogram of body weight as the dogs approached mature weight. Robinson *et al.* (1964) studied whether or not cholestyramine, a bile acid-binding resin, would interfere with vitamin K_1 absorption. In the resin dose range used in humans for control of hypercholesterolemia (200 mg/kg of body weight), there was no measurable effect on vitamin K_1 absorption. At larger resin doses (1–3 g/kg of body weight), vitamin K_1 absorption was decreased and delayed somewhat.

Clark and Halliwell (1963) administered 2.2 mg of warfarin, 3-(α-acetonylbenzyl)-4-hydroxycoumarin, per kilogram of body weight to adult Greyhounds daily for 3 days. This decreased prothrombin time to 10 percent of normal. Subsequent daily intravenous administration of vitamin K_1 at levels of 0.28–4.4 mg/kg of body weight returned prothrombin time to 70 percent of normal in 2–4 days, although the higher dosages produced a more rapid response. One oral dose of 2.2 mg of vitamin K_1 per kilogram of body weight returned prothrombin time to 70 percent of normal in 8 hours, but this value declined to 40 percent at 24 hours. Intramuscular dosage of vitamin K_1 produced a slower, but more sustained, response. Menadione (menaquinone, or 2-methyl-1, 4-naphthoquinone) and 2-methyl-1,4-naphthohydroquinone diphosphate administration did not produce a prothrombin response.

Whether dietary vitamin K is likely to be limiting in the absence of compounds that interfere with bacterial vitamin K synthesis, vitamin K absorption or function is not clearly established. Bratt *et al.* (1965) reported a suspected vitamin K deficiency is newborn pups that occasionally responded to vitamin K therapy. There were no controls. Reber and Malhotra (1961) fed a diet calculated to contain 60 μg of vitamin K per kilogram of solids to adult male Beagles for 40 weeks. No evidence of vitamin K deficiency was seen in the dogs or in adult cats fed the same diet, but 75 percent of weanling Sprague–Dawley rats fed this diet died from hemorrhage.

Although it is doubtful that supplemental vitamin K is necessary for the normal dog, it may be prudent to provide 22 μg of menadione (or vitamin K equivalent) per kilogram of body weight daily for adult maintenance and 44 μg/kg of body weight for growth. This would be supplied by a dry diet concentration of 1.0 mg menadione per kilogram.

Signs of Deficiency A simple vitamin K deficiency has not been described in the dog. When vitamin K absorption is produced by cholecystonephrostomy (Quick *et al.*, 1962), dogs become hypoprothrombinemic and exhibit massive hemorrhage. Similar signs appear subsequent to coumarin administration (Clark and Halliwell, 1963). Coumarins also induce liver parenchymal cell ultrastructure changes (Barnhart *et al.*, 1964), such as collapse of membranous elements of the endoplasmic reticulum around the mitochondria and reduced cytoplasmic ribosome concentration.

Hypervitaminosis K Vitamin K_1 is apparently safer in large quantities than the water-soluble analogs and derivatives of menadione (vitamin K_3). The latter are widely employed but may produce toxic side effects in the newborn when administered parenterally. Doses up to 10–25 mg of vitamin K have been administered to pregnant women prior to and during delivery, or to the newborn infant, to prevent hypoprothrombinemia and hemorrhagic disease in the child. When vitamin K_1 was used, this practice was apparently not harmful; however, 5–10 mg of menadiol sodium diphosphate administered daily to infants produced hemolytic anemia, and 10 mg given three times a day for 3 days to premature infants resulted in kernicterus and death. The mechanism of toxicity involves erythrocyte hemolysis and subsequent overloading of an immature liver with bilirubin, which cannot be sufficiently conjugated and which, in turn, proves toxic to the neonatal brain (kernicterus) (Hayes and Hegsted, 1973). While not described in the dog, the potential danger for this species is obvious. The relative hazard of oral versus parenteral administration is yet to be defined.

Thiamin

Requirements Descriptions of thiamin deficiency in the dog predate the discovery of the vitamin. Andrews reported in 1912 (Voegtlin and Lake, 1919) that polyneuritis developed in seven young puppies that were nursed by Philippine mothers whose infants had died of beriberi. Karr (1920) found that brewer's yeast was particularly effective in alleviating the clinical signs of this polyneuritis. Ultimately, thiamin was isolated and crystallized, and Cowgill (1934) reported that a daily intake of 6 μg of thiamin per kilogram of body weight was sufficient for mature dogs. Arnold and Elvehjem (1939a) concluded that 0.75 mg of thiamin chloride per kilogram of a 2-percent fat diet would meet the needs of growing or mature dogs, while dogs fed a 56-percent fat diet required only 0.28 mg of thiamin chloride per kilogram of diet. Requirements on the low-fat diet, expressed per kilogram of body weight, ranged from about 40 μg of thiamin chloride daily during early growth to 13 μg or less near maturity.

Using diets containing about 25-percent fat, Street *et al.* (1941) suggested adult dogs could be maintained in good health by daily intakes of 6.7–9.4 μg of thiamin per kilogram of body weight. Dogs fed an 11-percent fat diet were subjected to phlebotomy by Maass *et al.* (1944), who concluded that adult dogs could be maintained by 10 μg of thiamin per kilogram of body weight daily, while growing dogs required 10–25 μg/kg of body weight per day.

Noel *et al.* (1971) fed a low-thiamin, purified diet containing 5-percent fat to 24 Beagle puppies (initially 3–3.5 months old) for a 29-week period. The puppies were divided among four treatments: group 1 receiving 110 μg of thiamin per kilogram of body weight per day; group 2, 33 μg/kg/d; group 3, 22 μg/kg/d; and group 4, 115 μg/kg of body weight twice a week (total dosage equivalent to group 2). At the twenty-first week, a reduction in dose level was made for groups 1 and 4, and these lower levels were maintained for approximately 8 weeks. During this final period, group 1 received 11 μg of thiamin per kilogram of body weight per day, and group 4 received 77 μg/kg of body weight twice a week (total dosage equivalent to group 3). No clinical abnormalities were detected during the study except in one dog in group 2, which began to lose weight after 9 weeks and died at 22 weeks. Although anorexia was apparent in this dog just before death, and reduced erythrocyte transketolase activity and the transketolase response to thiamin pyrophosphate suggested a thiamin deficiency, all other dogs in group 2 appeared normal. Final thiamin concentrations in liver, heart, kidney, and skeletal muscle were not significantly different between treatments.

It has been established (Drill, 1941; Drill and Hays, 1942; Drill and Shaffer, 1942) that experimental hyperthyroidism will increase thiamin requirements of the dog when expressed per unit of body weight. However, the hyperthyroid dog consumes more food and, when thiamin requirements are expressed per unit of diet, there seems to be little, if any, change from normal.

There are a number of naturally occurring antivitamins of thiamin that modify thiamin structure and may increase dietary need. Some of these are thiaminases, which may be found in raw fish (e.g., carp), shellfish, ferns, bacteria, yeast, and fungi and which have produced typical thiamin deficiency signs in foxes (Green, 1936). Since thiaminases are heat-labile, they may be readily destroyed by cooking. However, some higher plants contain thiamin antagonists that are small, thermostable molecules that have been identified as *o*-dihydric phenols (e.g., 3,4-dihydroxy cinnamic acid or caffeic acid) (Davis and Somogyi, 1969). These are not normally of practical significance in the diet of the dog.

The thiamin requirements of the normal dog can be met by 22 μg/kg of body weight daily for adult maintenance and 44 μg/kg of body weight daily for growth. These amounts will be supplied by a concentration of 1 mg of thiamin per kilogram of dry diet.

Signs of Deficiency Thiamin deficiency in the dog results in anorexia, vomiting, impaired gastric secretion, unsteadiness, moderate spasticity of the hind legs, loss of deep reflexes of the hind legs, loss of conditioned salivary reflexes, myelin degeneration of peripheral nerves and posterior columns of the spinal cord, decreased erythrocyte transketolase activity and increased amounts of erythrocyte apotransketolase, dilatation and hypertrophy of the right ventricle, acute heart failure and death (Street *et al.*, 1941; Petrovskaja, 1958; Lavers *et al.*, 1959; Brin and Vincent, 1965).

Hypervitaminosis Thiamin Rapid intravenous injections of 5–50 mg of thiamin per kilogram of body weight cause a transient fall in blood pressure, with more severe effects from higher dosages. The lethal dose is approximately 350 mg/kg of body weight, and death is due to depression of the respiratory center. Under ether anesthesia, blood thiamin concentrations of 7–10 mg/100 ml were fatal. The ratios of lethal intravenous doses to those administered subcutaneously or orally were estimated to be 1:6:40 (Unna, 1954).

Riboflavin

Requirements Using adult mongrel dogs (6–8.5 kg of body weight) and a basal diet containing 30-percent casein, 36-percent sucrose, and 27-percent fat, Street and Cowgill (1939) concluded that 25 μg riboflavin per kilogram of body weight daily were adequate to maintain health for 130–196 days. With similar adult dogs and the same basal diet, Street *et al.* (1941) found that 4–8 μg riboflavin per kilogram of body weight daily were inadequate, but 25 μg riboflavin per kilogram of body weight daily maintained health for at least 500 days.

For the growing dog, Axelrod *et al.* (1941) concluded that 2–4 mg of riboflavin per kilogram of diet or 100–200 μg per kilogram of body weight daily were required. In a later study by this group (Potter *et al.*, 1942), the requirements for growth were revised downward to 60–100 μg per kilogram of body weight daily, and the isocaloric substitution of lard for sucrose in the diet was found not to increase the riboflavin requirement. Spector *et al.* (1943) subjected heavy-breed mongrel puppies to repeated phlebotomy on a riboflavin-deficient diet and found that recovery from the consequent anemia was suboptimal on 20 μg riboflavin per kilogram of body weight per day, but a 30-μg level supported good growth and hemoglobin production. Using Beagle puppies, Noel *et al.* (1972) established that 46–63 μg per kilogram of body weight were marginal to inadequate.

It is concluded that 48 μg riboflavin per kilogram of body weight daily is adequate for adult maintenance and 96 μg per kilogram of body weight daily is adequate for growth of puppies. These levels will be supplied by 2.2 mg riboflavin per kilogram of dry diet.

Signs of Deficiency Acute riboflavin deficiency may result in decreased respiration rate, a decline in body temperature, progressive weakness, apathy, tachycardia, sudden collapse, coma, and death (Street and Cowgill, 1939). Chronic riboflavin deficiency may result in loss in weight, anorexia, muscular weakness of the hindquarters, dermatitis, a mild microcytic, hypochromic anemia, conjunctivitis, corneal vascularization, corneal opacities, reduced erythrocyte riboflavin concentration, and reduced urinary riboflavin excretion (Axelrod *et al.*, 1939–1940; Axelrod *et al.*, 1941; Street *et al.*, 1941; Potter *et al.*, 1942; Spector *et al.*, 1943; Heywood and Partington, 1971; Noel *et al.*, 1972).

Pantothenic Acid

Requirements The need for pantothenic acid in the diet of the dog was suggested by data of McKibbin *et al.* (1939–1940), Morgan and Simms (1940) and Fouts *et al.* (1940). Few studies have been conducted that are suitable as a basis for setting minimum requirements. Schaefer *et al.* (1942), using weanling mongrel puppies and a diet containing 66-percent sucrose, 19-percent casein, and 11-percent fat, concluded that 60 μg of calcium pantothenate per kilogram of body weight daily was inadequate, while 100 μg per kilogram of body weight daily prevented deficiency signs. Sheffy (1964) depleted 4- to 5-week-old Beagle puppies on a pantothenic acid-deficient diet containing 64-percent sucrose and glucose, 20-percent casein, and 10-percent fat and then provided daily supplements of approximately 50, 100, 200, 500, or 1000 μg calcium pantothenate per kilogram of body weight. Dogs receiving no calcium pantothenate or the 50-μg level died between the third and sixth week. No significant differences in weight gain were noted in dogs on the three higher levels, although the antibody response to distemper virus and infectious canine hepatitis virus appeared earlier in dogs receiving 500 or 1000 μg calcium pantothenate per kilogram of body weight daily. Fourteen days after virus inoculation, the antibody response on the 200-, 500-, and 1000-μg levels was equal.

The conclusion, based on the above studies and research with other species, was that 220 μg of pantothenic acid per kilogram of body weight daily should be adequate for adult maintenance, and 440 μg of pantothenic acid per kilogram of body weight daily should be adequate for growth. These levels will be supplied by 10 mg of pantothenic acid per kilogram of dry diet.

Signs of Deficiency Pantothenic acid-deficient dogs develop erratic appetites, grow more slowly, exhibit a reduced antibody response to virus infection (Sheffy, 1964), reduced blood concentrations of cholesterol, cholesterol esters, phospholipids and total lipids (Scudi and Hamlin, 1942), decreased urinary pantothenic acid excretion and lower blood, liver, muscle, and brain levels (Silber, 1944), loss of conditioned reflexes (Gantt *et al.*, 1959), alopecia, vomition, intermittent diarrhea, gastritis, enteritis, gastrointestinal ulcers, fatty metamorphosis of the liver, Nissl's degeneration of central nervous system neurons, convulsions, coma, and death (Schaefer *et al.*, 1942; Das, 1962).

Niacin (Nicotinic Acid or Nicotinamide)

Requirements Studies of pellagra in humans preceded recognition of niacin deficiency in dogs. Goldberger and Wheeler (1920) established the deficient dietary etiology of this disease and demonstrated the similarity of pellagra and canine blacktongue (Goldberger and Wheeler, 1928). Although not proposed as a minimum requirement, Street and Cowgill (1937) were able to cure canine blacktongue with oral administration of 5 mg of nicotinic acid hydrochloride per kilogram of body weight per day. Sebrell *et al.* (1938) placed five adult dogs on a niacin-deficient diet and administered differing doses of nicotinic acid semiweekly by intramuscular injection. Expressed per kilogram of body weight daily, 125 μg of nicotinic acid resulted in incipient signs of deficiency, while 393 μg prevented deficiency signs. Margolis *et al.* (1938) produced canine blacktongue in adult dogs and found that intramuscular injections of 500 μg of nicotinic acid per kilogram of body weight per day resulted in prompt recovery, while with a 200-μg level the curative response was delayed. Birch (1939) found, with adult dogs, that oral intakes of 84 μg of nicotinic acid per kilogram of body weight daily were inadequate to prevent niacin deficiency, whereas 130 μg gave complete protection but only slow increases in weight, and 250 μg per kilogram of body weight daily gave complete protection and rapid increases in weight.

Schaefer *et al.* (1942) fed a diet containing 66-percent sucrose, 19-percent casein, and 11-percent fat to weanling mongrel puppies and older growing dogs. They concluded that the dietary nicotinic acid requirement for adult dogs was 200–225 μg per kilogram of body weight per day and for young growing puppies was 250–365 μg.

The quantitative requirement for niacin is influenced by dietary tryptophan, which can be metabolically converted to niacin. Singal *et al.* (1948) fed a semipurified diet containing 19-percent casein, 66-percent sucrose, and 11-percent cottonseed oil to weanling, mongrel puppies and produced niacin deficiency in about 2 weeks. When 21 percent of the sucrose was replaced by an equal amount of casein (total casein in the diet, 40 percent), the onset of niacin deficiency was significantly delayed. When 0.5 percent L-tryptophan was added to the basal diet, or when total casein in the diet was increased to 61 percent, complete protection against niacin deficiency was afforded. Further work established that the addition of 0.1 percent DL-tryptophan to the basal diet also offered complete protection against niacin deficiency, and, since the D-isomer appeared inactive, the total effective dietary tryptophan (L-isomer) concentration was estimated to be 0.28 percent. It is not clear why the 40-percent casein diet, containing an estimated 0.48 percent L-tryptophan, was not completely effective. These workers concluded that 1 g of L-tryptophan was equivalent to approximately 7.6 mg of nicotinic acid for oral treatment of niacin deficiency in the growing dog.

Ghosh *et al.* (1963) reported that 85–90 percent of the total nicotinic acid in cereals is in a bound form, that is alkali-labile. Oilseeds contain about 40 percent of their total nicotinic acid in bound form, while none of the nicotinic acid in pulses, yeast, crustacea, fish, animal tissues, and milk is bound. This bound nicotinic acid is unavailable or only partly available unless hydrolyzed by dilute alkali, and the niacin content of cereals should probably be ignored when calculating the contribution of natural ingredients to the dietary niacin supply.

Poor nicotinic acid availability in corn may not entirely explain the ease with which niacin deficiency can be produced on corn diets. Corn protein is also known to be low in tryptophan, but whether this entirely explains a 3-times higher nicotinic acid requirement for dogs on a corn grits diet as compared to a casein diet (Krehl *et al.*, 1945) has been questioned (Belavady and Gopalan, 1966). These latter workers reported that pellagra was comon among people whose main dietary staple was jowar (Indian millet, *Sorghum vulgare*), even though much of the nicotinic acid in this seed appeared to be available. Unlike corn, the tryptophan content of jowar is not low, but, like corn, its leucine content is high (14 g leucine per 100 g protein). Belavady *et al.* (1967) fed a basal diet containing 18-percent casein, 67-percent sucrose, and 11-percent cottonseed oil to weaned puppies, which also received an oral supplement of 300 μg of nicotinic acid per kilogram of body weight daily. This diet supplied 1.5-percent leucine, and all pups appeared normal and grew satisfactorily. When an additional supplement of 1.2-percent leucine (raising the total leucine to 2.7 percent) was provided, all pups on this treatment developed signs of niacin deficiency within 2–4 months, suggesting an adverse effect upon tryptophan and/or niacin metabolism. Hankes *et al.* (1971) concluded that the high leucine content of corn depressed synthesis of nicotinamide adenine dinucleotide phosphate in the body.

West (1941) and Schaefer *et al.* (1942) have reported that niacin metabolism in dogs may also be adversely affected by dietary inclusion of sulfapyridine.

It is concluded that, with usual diets, the requirements for adult maintenance will be met by 250 μg of niacin per kilogram of body weight daily and requirements for growth by 500 μg. These amounts will be supplied by 11.4 mg of niacin per kilogram of dry diet. Nicotinic acid or nicotinamide appear to be equally active (Elvehjem *et al.*, 1938).

Signs of Deficiency Niacin-deficient dogs exhibit loss in weight, anorexia, inflammation and ulceration of the oral and pharyngeal mucosa, profuse salivation with ropy, blood-stained drooling from the mouth and foul breath. There is bloody diarrhea, inflammation and hemorrhagic necrosis of the duodenum and jejunum with shortening and clubbing of villi, and inflammation and degeneration of the mucosa of the large intestine. Intestinal absorption of water, glucose, sodium, and potassium is reduced. Hepatic periportal fatty metamorphosis, neuronal degeneration of the spinal cord, and distortion of conditioned reflexes are evident. Urinary excretion of trigonelline is decreased, and there are decreased liver and skeletal muscle concentrations of nicotinamide adenine dinucleotide and nicotinamide adenine dinucleotide phosphate. Uncorrected deficiencies lead to dehydration, emaciation, and death (Dann and Handler, 1941; Schaefer *et al.*, 1942; Sarett, 1942; Handler, 1943; Smith *et al.*, 1943; Layne and Carey, 1944; Efremov *et al.*, 1954; Nelson *et al.*, 1962; Belavady and Gopalan, 1965; Greengard *et al.*, 1966; Madhavan *et al.*, 1968).

Hypervitaminosis Niacin High doses of nicotinic acid (but not nicotinamide) have been shown to cause vasodilatation and increased intracranial blood flow in man. Oral doses of 100–300 mg in the human may produce these phenomena, and they may be accompanied by transient side effects such as pruritus and cutaneous desquamation. A cutaneous flush in dogs appeared within 10 minutes of intravenous injection of 1–100 mg of nicotinic acid per kilogram of body weight (Pereira, 1967). These injections also produced a transient decline in plasma free fatty acid concentrations possibly due to an inhibitory effect on norepinephrine-induced lipolysis (Pereira and Mears, 1971). Although there are variable reports on the effect of nicotinic acid upon hypercholesterolemia in the dog (Grande and Amatuzio, 1960; Zanetti and Tennent, 1963), Grande (1966) established that nicotinic acid has a plasma cholesterol-depressing effect in normal dogs that depends upon the dose used and the initial cholesterol level. When 66 mg of nicotinic acid per kilogram of body weight was given orally each day for 2 weeks to dogs on a low-fat diet, no effect on plasma cholesterol was noted. However, when this dose was given to dogs on a diet containing 15-percent coconut oil, initial plasma cholesterol levels were elevated, and nicotinic acid treatment caused them to decline. When the daily dose of nicotinic acid was increased approximately one-third, plasma cholesterol concentrations declined, whether the dogs consumed a 3-percent or a 25-percent fat diet.

Vitamin B_6 (Pyridoxine, Pyridoxal, and Pyridoxamine)

Requirements Fouts *et al.* (1938) fed a semipurified diet to weaned puppies and induced a vitamin B_6 deficiency (microcytic, hypochromic anemia) that could be overcome by daily oral administration of 60 μg/kg of body weight (Fouts *et al.*, 1939; McKibbin *et al.*, 1939–1940; Borson and Mettier, 1940). Street *et al.* (1941) found that a semipurified diet also produced signs of vitamin B_6 deficiency in adult dogs—signs that could be prevented in pair-fed controls by oral doses of vitamins B_6 of 5 μg/kg/d. An *ad libitum*-fed control apparently had a daily vitamin B_6 requirement near 10 μg/kg of body weight. Michaud and Elvehjem (1944) noted that 5 μg vitamin B_6 per kilogram of body weight per day was inadequate for young, growing dogs and resulted in death. A 10-μg level allowed fairly good growth but not equal to that obtained with 60 μg/kg of body weight daily. They concluded that the requirement for growth fell between these two figures and was probably not much above 10 μg.

High protein diets (46-percent casein) may increase vitamin B_6 requirements somewhat as compared to moderate protein diets (18-percent casein) (Axelrod *et al.*, 1945).

A naturally-occurring heat stable vitamin B_6 antagonist has been isolated from flaxseed and named linatine (Klosterman *et al.*, 1967). It is easily hydrolyzed to 1-amino-D-proline, which forms a stable complex with pyridoxal phosphate, as does avidin with biotin, providing a potential for problems with vitamin B_6 deficiency on high linseed meal diets.

It is concluded that the vitamin B_6 requirements for adult maintenance will be met by 22 μg pyridoxine per kilogram of body weight per day and those for growth by 44 μg. These amounts will be supplied by 1 mg pyridoxine per kilogram of dry diet. Pyridoxal or pyridoxamine should be equally effective.

Signs of Deficiency Vitamin B_6 deficiency results in anorexia, slow growth or weight loss, microcytic hypochromic anemia, elevated plasma iron concentrations, epileptiform convulsions, and death (Fouts *et al.*, 1938, 1939; McKibbin *et al.*, 1939–1940; Borson and Mettier, 1940; Street *et al.*, 1941; McKibbin *et al.*, 1942). Dermatitis and alopecia have been occasionally, but not consistently, reported. A reversible loss in conditioned reflex function has been observed (Gantt *et al.*, 1959). When given oral doses of tryptophan (1.5–2.0 g), vitamin B_6-deficient dogs excreted kynurenine and xanthurenic acid in the urine as compared to normal dogs, which excreted kynurenine and kynurenic acid (Axelrod *et al.*, 1945). When combined with an essential fatty acid deficiency, vitamin B_6 deficiency was more likely to lead to early death (Söderhjelm, 1962). Chronic dietary vitamin B_6 deficiency has been shown to lengthen tolerance to skin homografts (Humphries *et al.*, 1961), and use of a vitamin B_6 antagonist, deoxypyridoxine, prolonged survival of dogs subjected to renal homotransplantation (Fisher *et al.*, 1963).

Hypervitaminosis Vitamin B_6 The vitamins B_6 are not considered highly toxic, and have been used in a relatively large dose (20 mg per kilogram of body weight intravenously) as an antidote to a rodenticide, "Castrix" (Ullrich, 1967), and to protect against the toxic pressor effects of strophanthin K (Eremeev, 1968).

Folacin (Folic Acid and Derivatives)

Requirements Folacin requirements for dogs have not been well defined. Krehl and Elvehjem (1945) concluded that on "complete synthetic diets," folic acid requirements of dogs were probably met by intestinal bacterial synthesis. However, when these workers produced a niacin deficiency in weanling puppies, they found that the response to nicotinic acid was enhanced by daily oral administration of about 4 μg of folic acid per kilogram of body weight. Ruegamer *et al.* (1948) fed a niacin-free basal diet containing 19-percent alcohol-extracted casein and 1-percent sulfasuxidine to weanling pups. Blacktongue developed in 14–18 days, and niacin was partially effective in overcoming the deficiency, although daily oral administration of about 12 μg of folic acid per kilogram of body weight plus niacin produced a more consistent weight gain response. Cure of the observed macrocytic anemia required an additional supplement of pernicious anemia factor (vitamin B_{12}?) in liver extract. When the protein concentration of the basal diet was increased to 24–30 percent, it was not possible to demonstrate a need for folic acid.

Afonsky (1954) described deficiency signs in a dog receiving a semipurified diet that responded to daily subcutaneous injections of 15 μg of folic acid per kilogram of body weight.

Sheffy (1964) depleted 4- to 5-week-old Beagle puppies on a semipurified diet containing 1-percent sulfasuxidine and studied their antibody response to infectious canine hepatitis and canine distemper. Supplemental levels of 14, 28, 55, and 550 μg of folic acid per kilogram of body weight per day were studied. A small, much delayed antibody response was evident even without supplementation, but, within 7 days of supplementation, all levels of folic acid produced an approximately equal response.

Luketic *et al.* (1965) reported that the intravenous injection of 0.24 mg of colchicine per kilogram of body weight in the dog produced a significant decline in whole blood folate concentration within 1–3 hours. These workers speculated that colchicine may interfere with enzymes involved in tetrahydrofolate recycling.

The folic acid requirement will probably be met by natural dietary ingredients and intestinal synthesis under most circumstances. On a purified diet (without intestinally active sulfa drugs or antibiotics), the folic acid requirements for adult maintenance should be met by 4 μg per kilogram of body weight per day and for growth of puppies by 8 μg. These amounts will be supplied by 0.18 mg of folic acid per kilogram of dry diet.

Signs of Deficiency Folacin deficiency results in erratic appetite, decreased weight gain, watery exudate from the eyes, glossitis, leukopenia, hypochromic anemia with a tendency to microcytosis and decreased antibody response to infectious canine hepatitis and canine distemper virus (Krehl and Elvehjem, 1945; Ruegamer *et al.*, 1948; Afonsky, 1954; Sheffy, 1964).

Hypervitaminosis Folacin Although oral toxicity of folacin has not been described in the dog, Vogel *et al.* (1964) demonstrated inhibition of hepatic alcohol dehydrogenase in the dog by intravenous administration of 80 mg of folic acid per kilogram of body weight 4 hours after intravenous ethanol infusion.

Biotin

Requirements Biotin requirements of the dog have not been established. The feeding of large quantities of raw or spray-dried egg white can produce signs of biotin deficiency due to the presence of avidin, a protein that forms a stable and biologically inactive complex with biotin. One molecule of avidin binds four of biotin (Green, 1963) so firmly that 15 min of steaming at 100 °C released only 0–10% of the bound biotin (Wei and Wright, 1964). Steaming for 2 h at 100 °C released 55–65% of the biotin, while autoclaving for 15 min at 120 °C produced complete dissociation. Uncombined avidin was found to be relatively heat-labile. Not only is avidin found in the white of bird's eggs but also in ovarian tissues during the laying period (Hertz and Sebrell, 1942).

Intestinally active antibiotics or sulfa drugs that inhibit microbial biotin synthesis may also be expected to increase the need for biotin in the diet. Greve (1963) fed diets containing spray-dried egg white and sulfaguanidine to dogs and produced evidence of biotin deficiency. Assay of the urine of these dogs revealed less than 0.05 pg biotin per ml as compared to "normal" dog urine that contained 7–13 pg biotin per milliliter. Unfortunately, the biotin concentration of the diet was not reported.

Siegel *et al.* (1967) have published biotin concentrations in maternal, prenatal, and postnatal dog tissues without any information on diet composition or biotin concentration.

The biotin requirement of the starting chicken has been set at 0.1 mg per kilogram of dry diet (NRC, 1971). This amount of biotin in the diet of the dog would supply 2.2 μg per kilogram of body weight daily for adult maintenance and 4.4 μg per kilogram of body weight daily for growth. While not proposed as a biotin requirement for the dog, these figures may be useful in formulating dog diets.

Signs of Deficiency No adequate descriptions of biotin deficiency in the dog are available. Greve (1963) reported scurfy skin, due to hyperkeratosis of the superficial and follicular epithelia, and a marked decline in urinary biotin concentration. No alopecia or achromotrichia was noted.

Vitamin B_{12}

Requirements Although a large number of papers have been published concerned with site and mechanism of vitamin B_{12} absorption in the dog (Reizenstein *et al.*, 1960; Fleming *et al.*, 1962; Hermann *et al.*, 1964; Bryant and Stafford, 1965; Gazet and McColl, 1967; Weisberg *et al.*, 1968; Yamaguchi *et al.*, 1969a, b; Lavrova, 1969; Taylor *et al.*, 1969; Weisberg and Rhodin, 1970), with plasma transport of vitamin B_{12} (Markelova, 1960; Rappazzo and Hall, 1972; Sonneborn *et al.*, 1972) and with tissue vitamin B_{12} distribution (Cooperman *et al.*, 1960; Woods *et al.*, 1960; Skeggs *et al.*, 1963; Rosenblum *et al.*, 1963), no definitive data on dietary vitamin B_{12} requirements are available. Arnrich *et al.* (1952) fed a semipurified diet containing 20-percent vitamin-free casein without supplemental vitamin B_{12} to weanling Cocker Spaniel puppies for 20 weeks. No anemia developed and gains were satisfactory, although a supplement of 50 μg of vitamin B_{12} per kilogram of diet appeared to increase gains (primarily fat) somewhat. Likewise, urinary vitamin B_{12} excretion has been studied in the dog (Nelp *et al.*, 1964; Coppi *et al.*, 1970), but no data were presented that would provide a guide to vitamin B_{12} status in relation to vitamin B_{12} intake.

In the absence of other information, it is recommended that the vitamin B_{12} requirement of the baby pig (NRC, 1973) be accepted for the dog. This would equal 0.5 μg of vitamin B_{12} per kilogram of body weight for adult maintenance and 1.0 μg of vitamin B_{12} per kilogram of body weight for growth of puppies. These amounts would be supplied by 22 μg (0.022 mg) of vitamin B_{12} per kilogram of dry diet.

Signs of Deficiency Uncomplicated vitamin B_{12} deficiency has not been described in the dog. Lavrova (1969) reported an anemia in dogs with an internal biliary fistula, which may have been associated with a failure in vitamin B_{12} absorption. The anemia was generally macrocytic hypochromic, macrocytic normochromic, normocytic hypochromic, or normocytic normochromic in type. The bone marrow erythropoietic centers appeared hypoplastic. Serum and liver vitamin B_{12} concentrations were decreased.

Hypervitaminosis B_{12} Although frank vitamin B_{12} toxicity has not been described in the dog, Pshonik and Gribanov (1961) noted disturbances of reflex activity in the form of reduction in size of vascular conditioned reflexes, exaggeration of unconditioned reflexes, and intensification of successive inhibition when vitamin B_{12} was injected subcutaneously in doses of 2–33 μg per kilogram of body weight.

Choline

Requirements The dietary requirement for choline is markedly affected by dietary protein concentration and, more specifically, by the dietary concentration of methionine. Since both choline and methionine may serve as labile methyl donors in metabolism, the dietary supply of one tends to spare the need for the other. Schaefer *et al.* (1941) pointed out that a number of workers have found that dietary casein concentrations of 40 percent or more tend to obviate the need for dietary choline. In their own studies, puppies receiving a 19-percent casein diet became choline deficient. Controls receiving 50 mg of choline per kilogram of body weight per day grew satisfactorily over the 37-day experimental period. On a 15-percent casein diet, Fouts (1943) found that 10 or 20 mg of choline per kilogram of body weight would not prevent or cure the deficiency state in puppies, while a 100-mg level would. When 41-percent casein was provided, no choline deficiency nor any response to supplemental choline could be shown.

McKibbin *et al.* (1944) fed a diet containing 10-percent protein from peanut flour plus 10-percent casein to puppies and concluded that choline requirements were probably not greater than 1000 mg per kilogram of diet or 50 mg per kilogram of body weight per day.

It is concluded that the choline requirements for adult maintenance may be met by 26 mg per kilogram of body weight per day and those for growth of puppies by 52 mg per kilogram of body weight per day. These amounts will be supplied by 1200 mg of choline per kilogram of dry diet.

Signs of Deficiency Dutra and McKibbin (1945) described the pathology of "uncomplicated" choline deficiency in young puppies. They reported fatty metamorphosis of the liver and atrophic changes of the thymus. The morphologic changes in the liver correlated with impairment in liver function as measured by delayed bromsulfalein elimination. Plasma phosphatase activity and blood prothrombin times were also elevated in the choline-deficient puppies.

Hypervitaminosis choline Acara and Rennick (1973) found 1.97×10^{-5} *M* endogenous choline in the plasma of dogs (presumably fed a normal diet). Renal clearance studies indicated that only one thirtieth of the choline filtered at the glomerulus was excreted in the urine, suggesting active tubular reabsorption. When exogenous choline was infused intravenously, choline renal clearance exceeded glomerular filtration rate, indicating active tubular excretion. Solomon (1966) has reported that infusion of choline results in urinary alkalinization, primarily from an increased urinary bicarbonate output. At the same time, there is a decrease in ammonia output.

Vitamin C (Ascorbic Acid)

Innes (1931) demonstrated that the dog is independent of an exogenous supply of vitamin C. Puppies completely deprived of vitamin C for 147–154 days showed no growth impairment nor lesions of bones or teeth, although the same diet killed guinea pigs within 25 days with severe signs of scurvy. Furthermore, the livers of dogs on the deficient diet contained the vitamin in sufficient amount to prevent the onset of scurvy in guinea pigs, indicating that the dog can synthesize its own vitamin C. Naismith (1958) showed that this synthetic ability is present in puppies during the first weeks of postnatal life. Litters were divided. Some puppies were left with the bitch; others were fed a synthetic diet minus vitamin C or plus vitamin C. No significant differences in blood ascorbic acid concentration were evident, regardless of treatment.

Despite this evidence, a number of equivocal reports (Garlick, 1946; Meier *et al.*, 1957; Ditchfield and Phillipson, 1960; Holmes, 1962; Sadek, 1962; Bendefy, 1965) have been published, purporting to describe scurvy in the dog. In addition, vitamin C has been proposed as a prophylactic agent against canine distemper (Belfield, 1967; Leveque, 1969), and some veterinary practitioners apparently use vitamin C in the treatment of kennel cough. Sheffy (1972) conducted some carefully controlled studies concerned with these issues and established that exogenous vitamin C was of no benefit in alleviating clinical signs of illness, mortality, or gross or microscopic pathology associated with experimentally produced canine herpes virus infection, kennel cough or infectious canine hepatitis. In addition, as determined by measuring blood ascorbic acid levels, the latter disease did not affect vitamin C synthesis. Other data on blood and urine ascorbic acid values in the dog have been published by Majumdar *et al.* (1964) and Kleit *et al.* (1965). Csaba and Toth (1966), in controlled studies, established that ascorbic acid given before antigen challenge in dogs has no protective action against anaphylactic shock and does not influence histamine release.

It is concluded that there is no adequate evidence to justify recommendation of routine vitamin C additions to the diet of the normal dog.

WATER

Water is undoubtedly the most important nutrient and is vital for the function of all living cells. The body of the adult dog contains about 60-percent water (Gaebler and Choitz, 1964), and this proportion is even higher in the puppy. The body has no significant capacity to store water, and water deprivation causes death much more quickly than deprivation of food.

Dogs obtain water in liquid form, from food and as a consequence of oxidation of hydrogen during metabolism, the latter known as metabolic water. Oxidation of 100 g of protein yields about 40 g of metabolic water, 100 g of carbohydrate about 55 g, and 100 g of fat about 107 g. In general, about 10–16 g of metabolic water is produced for each 100 kcal of energy metabolized. Thus, a dog consuming 2000 kcal of metabolizable energy per day may derive 200–320 g of water from body metabolism.

Water gain (whether from liquid water, food, or metabolic water) is balanced by water loss, principally through the urine, lungs, skin, and feces. In the lactating bitch, a considerable amount of water is lost in the milk.

Under normal conditions, the body water content is remarkably constant. Therefore, water intake plus metabolic water must balance water outgo. The dog can cope with a large fluid intake by virtue of a readily adjustable urine volume, but the unsalvageable water losses of the body dictate the minimum intake. In the growing puppy and the idle adult, voluntary water intake will usually range from 2- to 3-times the dry matter intake. During lactation, hot weather, or severe exertion, water intakes may reach 4- or more times dry matter intake.

The individual dog's requirement for drinking water is self-regulated, depending on factors such as type of food, environmental temperature, amount of exercise, physiological state, and temperament. The need can be met by permitting free access to water at all times or by offering water at least three times a day. A dog should not be allowed large amounts of cold water immediately following violent exercise because of the dangers of water intoxication. When the total ration consists of soft-moist foods, which contain an intermediate amount of water, or of dry-type dog foods, water is a necessary adjunct to feeding.

COMPOSITION OF FEEDS

Tables 6 and 7 give the composition of feeds commonly used in dog diets.* Two larger compilations are available.†

NRC NOMENCLATURE

In Tables 6 and 7 and in Publications 1684 and 1919, names of the feeds are based on a scheme proposed by Harris *et al.* (1968). The names, called NRC (National Research Council) or International names, are designed to give a qualitative description of each product, where such information is available and pertinent. A complete NRC name consists of as many as eight components separated by commas and written in linear form. The components are as follows:

Origin (or parent material)
Species, variety, or kind
Part eaten
Process(es) and treatment(s) to which product has been subjected
Stage of maturity
Cutting or crop
Grade or quality designations
Classification

Feeds of the same origin (and the same species, variety, or kind, if one of these is stated) are grouped into eight classes, each of which is designated by a number in parentheses. The numbers and the classes they designate are as follows:

1. Dry forages or dry roughages
2. Pasture, range plants, and feeds fed green
3. Silages
4. Energy feeds
5. Protein supplements
6. Minerals
7. Vitamins
8. Additives

Feeds that in the dry state contain, on the average, more than 18 percent of crude fiber are classified as forages or roughages. Feeds that contain 20 percent or more of protein are classified as protein supplements. Products that contain less than 20 percent of protein are classified as energy feeds. (These guidelines are approximate, and there is some overlapping.)

Abbreviations have been devised for some of the terms in the NRC feed names (Table 8).

The following list shows how three feeds are described:

Components of Name	Feed No. 1	Feed No. 2	Feed No. 3
Origin (or parent material)	Alfalfa	Animal	Cattle
Species, variety, or kind	—	—	—
Part eaten	aerial part	carcass residue	milk
Process(es) and treatment(s) to which product has been subjected	dehy grnd	dry rendered, dehy grnd	skim dehy
Stage of maturity	early bloom	—	—
Cutting or crop	cut 1	—	—
Grade or quality designations	mn 17% protein	mx 4.4% phosphorus	mx 8% moisture

* The data in these tables were prepared by the International Feedstuffs Institute (L. E. Harris, Director), Utah State University, Logan.

† Publication 1684, United States–Canadian Tables of Feed Composition, lists about 400 feeds. Publication 1919, Atlas of Nutritional Data on United States and Canadian Feeds, lists about 6,150 feeds. Both are published by the National Academy of Sciences, Washington, D. C.

Components of Name	Feed No. 1	Feed No. 2	Feed No. 3
Classification	(1) (dry forages)	(5) (protein supplements)	(5) (protein supplements)

Thus, the NRC names of the three feeds are written as follows:

No. 1: Alfalfa, aerial part, dehy grnd, early bloom, cut 1, mn 17% protein, (1)

No. 2: Animal, carcass residue, dry rendered, dehy grnd, mx 4.4% phosphorus, (5)

No. 3: Cattle, milk, skim dehy, mx 8% moisture, (5)

The analytical data are expressed in the metric system (with the exception of the bushel weights of the cereal grains) and are shown on a dry basis. See Table 9 for weight-unit conversion factors and Table 10 for weight equivalents.

Analytical data may differ in the various NRC reports because the data are up-dated for each report. The NRC names may also differ as feeds are more precisely characterized or as official definitions change. However, if the feed is the same, the International reference number will remain the same.

LOCATING NAMES IN THE TABLES

To locate in Tables 6 and 7 the NRC name of a feed, one must know the name of the parent material (i.e., the origin of the feed) and usually the variety or kind of parent material. The first word of each NRC name is the name of the parent material. For a feed derived from a plant, the origin term is the name of the plant (e.g., alfalfa, barley, oats), not the word *plant*.

Names having the same origin term are arranged in an order that depends on whether the names include references to species, variety, or kind. Names lacking such references are arranged under the origin term as follows:

First: numerically, by classes

Second (within a class): alphabetically, by parts eaten, process(es), stage of maturity (in the order in which stages occur), cutting, and grade

Names that include references to species, variety, or kind are arranged under the origin term as follows:

First: alphabetically, by species, variety or kind

Second (within species, variety, or kind): numerically, by classes

Third (within a class): alphabetically, by parts eaten, process(es), stage of maturity (in the order in which the stages occur), cutting, and grade

Many feeds have names that were given to them by the Association of American Feed Control Officials (AAFCO), the Canada Feed Act (CFA), or the Canada Grain Act (CGA). In addition, some feeds have regional or local names. The reader will find these names in their alphabetical place, where they are crossreferenced to the NRC names; he will also find them under the NRC names.

A 6-digit International reference number is listed after the NRC name and other names. The first digit is the class of the feed. The numbers may be used as the "numerical name" of a feed when performing linear programing with electronic computers.

The common name of the parent material is followed by the scientific name. (Example: Alfalfa. *Medicago sativa.*)

CAROTENE CONVERSION

International standards for vitamin A activity as related to vitamin A and β-carotene are as follows:

1 IU of vitamin A = 1 USP unit
= vitamin A activity of 0.300 μg of crystalline all-*trans* retinol (vitamin A alcohol), which corresponds to 0.344 μg of all-*trans* retinyl acetate (vitamin A acetate) or 0.550 μg of all-*trans* retinyl palmitate (vitamin A palmitate)

β-Carotene is the standard for provitamin A.

1 IU of Vitamin A = 0.6 μg of all-*trans* β-carotene

1 mg of β-carotene = 1667 IU of vitamin A

International standards for vitamin A are based on the utilization of vitamin A and β-carotene by the rat. Since it is not well established that dogs convert carotene to vitamin A in the same ratio as rats, it is suggested that the provitamin A (carotene) values in Table 6 (when used in connection with Tables 1 and 2) be converted as follows:

1 mg of provitamin A (carotene) = 833 IU of vitamin A activity for the dog

METABOLIZABLE ENERGY (ME)

Since ME values for dog food ingredients have not been published, the figures in Table 6 are estimates based on assumed apparent digestibilities of 80 percent for protein (or 75 percent in feeds high in connective tissue), 92 percent for ether extract and 85 percent for nitrogen-free extract. These digestion coefficients were multiplied by gross energy values of 4.4 (5.65 – 1.25)*, 9.4 and 4.15 kcal/g for protein, ether extract, and NFE, respectively. It was assumed that no ME was derived from crude fiber.

* Gross energy of protein corrected for nitrogen energy loss in urine.

FORMULATED DIETS FOR DOGS

Dogs require specific nutrients, not specific feedstuffs. This fact and the remarkable adaptability of the dog has led to the successful use of commercial diets that differ widely in their ingredient composition. Commercial dog foods are of the three basic types described below:

1. *Dry-type dog foods*

Low in moisture content (usually about 10–12%), these foods commonly contain whole or dehulled cereal grains (e.g., corn, wheat, oats, barley), cereal by-products (e.g., wheat middlings, wheat germ meal, corn gluten meal), soybean products (e.g., soybean meal, soy grits), animal products (e.g., meat meal, meat and bone meal, meat by-products, poultry by-products), milk products (e.g., dried skimmed milk, dried whey), fats and oils (e.g., animal fat), mineral and vitamin supplements. Crude fat content usually ranges from 5 to 12.5% on a dry basis. The higher fat levels (and improved palatability) may be achieved by spraying a liquefied fat on the surface of a pelleted or extruded product. Dry-type foods may be marketed as meals, pellets, biscuits, kibbles (broken biscuits) or expanded (extruded) products. Processing methods should include sufficient heat to partially dextrinize starch for improved digestibility.

2. *Semimoist dog foods*

Moderate in moisture content (usually 25–30%), these foods are protected against spoilage without refrigeration by their content of sucrose, propylene glycol, and sorbates. They also commonly contain animal products (e.g., meat, meat by-products), milk products (e.g., cheese rind), fats and oils (e.g., animal fat), soybean products (e.g., soybean meal, soy flour), carboxymethyl-cellulose, mineral and vitamin supplements. They may be shaped into "patties" of a size convenient for feeding or packaged as simulated meat chunks.

3. *Canned dog foods*

High in moisture content (usually 74–78%), these foods are commonly formulated to be nutritionally complete or to serve as a palatable, but nutritionally incomplete, food "supplement." Those that are nutritionally complete may be either a dry-type formula to which water has been added and the product canned, or they may be high-fat, meat products containing animal products (e.g., meat, meat by-products), fats and oils (e.g., soybean oil), mineral and vitamin supplements. Depending upon economic factors, soybean products may also be present. The high energy density associated with the high-fat content dictates concentrations of protein, minerals, and vitamins that are higher on a dry basis than indicated in Table 1 to ensure adequate nutrient–calorie ratios. Nutritionally incomplete food "supplements" may contain only animal products (e.g., meat, meat by-products). Since the muscles, organs, and visceral tissues found in these products are extremely low in calcium and suboptimal in phosphorus and other nutrients, their exclusive or excessive use as a substitute for a nutritionally complete diet may lead to serious deficiency disease (Hartley *et al.*, 1963; Goddard *et al.*, 1970; Gorham *et al.*, 1970; Morris *et al.*, 1971).

Formulas for two dry-type dog diets are presented in Table 11. They have been used successfully in research kennels, although they may not be as palatable as some commercial products. These formulas are intended to serve only as examples, and other combinations of ingredients may serve as well or better. Although additions of milk, meat, broths, or other materials may improve palatability, they do not necessarily increase the nutritional value of properly balanced dry-type diets.

TABLES

TABLE 1 Nutrient Requirements (and Selected Recommended Allowances) of Dogs (percentage or amount per kilogram of food)[a]

		Type of Diet			
		Dry Basis	Dry Type	Semimoist	Canned or Wet
Moisture level (%)		0	10	25	75
Dry matter basis (%)		100	90	75	25
Nutrient		Requirement			
Protein	%	22	20	16.5	5.5
Fat	%	5.0	4.5	3.75	1.25
Linoleic acid	%	1.0	0.9	0.75	0.25
Minerals					
Calcium	%	1.1	1.0	0.8	0.3
Phosphorus	%	0.9	0.8	0.7	0.22
Potassium	%	0.6	0.5	0.45	0.2
Sodium chloride	%	1.1	1.0	0.8	0.3
Magnesium	%	0.040	0.036	0.030	0.010
Iron	mg	60	54	45	15
Copper	mg	7.3	6.5	5.5	1.8
Manganese	mg	5.0	4.5	3.8	1.2
Zinc[b]	mg	50	45	38	12
Iodine	mg	1.54	1.39	1.16	0.39
Selenium[b]	mg	0.11	0.10	0.08	0.03
Vitamins					
Vitamin A	IU	5,000[c]	4,500	3,750	1,250
Vitamin D	IU	500[d]	450	375	125
Vitamin E	IU	50[e]	45	37.5	12.5
Thiamin	mg	1.00	0.90	0.75	0.25
Riboflavin	mg	2.2	2.0	1.6	0.5
Pantothenic acid	mg	10.0	9.0	7.5	2.5
Niacin	mg	11.4	10.3	8.6	2.8
Pyridoxine	mg	1.0	0.9	0.75	0.25
Folic acid	mg	0.18	0.16	0.14	0.04
Biotin[b]	mg	0.10	0.09	0.075	0.025
Vitamin B_{12}[b]	mg	0.022	0.020	0.017	0.006
Choline	mg	1,200	1,100	900	300

[a]Based on diets with ME concentrations in the range of 3.5–4.0 kcal/g of dry matter. If energy density exceeds this range, it may be necessary to increase nutrient concentrations proportionately (see pp. 3, 5, and 8 for discussion of nutrient–caloric interrelationships). Recommended nutrient levels selected to meet the requirements of the most demanding life cycle segments, i.e., rapid growth and lactation.

[b]Recommended allowance based on research with other species.

[c]This amount of vitamin A activity corresponds to 1.5 mg of all-*trans* retinol per kilogram of dry diet (One IU of vitamin A activity equals 0.3 μg of all-*trans* retinol).

[d]This amount of vitamin D activity corresponds to 12.5 μg of cholecalciferol per kilogram of dry diet (One IU of vitamin D activity equals 0.025 μg of cholecalciferol).

[e]This amount of vitamin E activity corresponds to 50 mg of *dl*-α-tocopheryl acetate per kilogram of dry diet (One IU of vitamin E activity equals 1 mg of *dl*-α-tocopheryl acetate).

TABLE 2 Nutrient Requirements (and Selected Recommended Allowances) of Dogs (amounts per kilogram of body weight per day)[a]

Nutrient		Adult Maintenance	Growing Puppies
Protein	g	4.8	9.6
Fat	g	1.1	2.2
Linoleic acid	g	0.22	0.44
Minerals			
Calcium	mg	242	484
Phosphorus	mg	198	396
Potassium	mg	132	264
Sodium chloride	mg	242	484
Magnesium	mg	8.8	17.6
Iron	mg	1.32	2.64
Copper	mg	0.16	0.32
Manganese	mg	0.11	0.22
Zinc	mg	1.1	2.2
Iodine	mg	0.034	0.068
Selenium	μg	2.42	4.84
Vitamins			
Vitamin A	IU	110	220
Vitamin D	IU	11	22
Vitamin E	IU	1.1	2.2
Thiamin	μg	22	44
Riboflavin	μg	48	96
Pantothenic acid	μg	220	440
Niacin	μg	250	500
Pyridoxine	μg	22	44
Folic acid	μg	4.0	8.0
Biotin	μg	2.2	4.4
Vitamin B_{12}	μg	0.5	1.0
Choline	mg	26	52

[a]These data may be related to those in Table 1 by assuming 22 g of dry matter consumption per kilogram of body weight by adult dogs for maintenance and double this consumption by growing puppies. Adult dogs which are working or lactating will consume 2-3 times the food consumed by the adult dog for maintenance, and thus daily nutrient intakes per kilogram body weight will equal or exceed those levels ingested by growing puppies.

TABLE 3 Apparent Metabolizable Protein and Apparent Metabolizable Energy Requirements of Dogs in Different Physiological States[a]

Physiological State	Protein Requirement (g metabolizable protein per $W_{kg}^{0.75}$ per day)	Metabolizable Energy Requirement (kcal per $W_{kg}^{0.75}$ per day)	Protein Value of Diet (ND_p Cal %)[b]
Weaning			
Start (3 wk)	8.1	274	11.8
Finish (6 wk)	6.5	274	9.6
Half grown	3.8	200	7.6
Adult	1.5	132	4.6
Pregnancy, late	5.7	188	12.1
Lactation	12.4	470	10.6

[a]Adapted from Payne (1965). Apparent metabolizable protein equals food nitrogen minus fecal and urine N (retained N) × 6.25.

Apparent metabolizable energy estimates were based on 4 kcal/g of dietary carbohydrate and protein and 9 kcal/g of dietary fat.

These requirements are presumed to apply in a thermoneutral environment at moderate levels of activity.

[b]Net Dietary-protein Calories percent (Platt *et al.*, 1961) equals

$$\frac{\text{retained N (g)} \times 6.25 \times 4 \text{ kcal}}{\text{total food intake (g)} \times \text{ME in food (kcal/g)}} \times 100.$$

TABLE 4 Estimated Daily Food Requirements for Maintenance of Dogs of Various Weights[a]

Weight of Dog		ME Required	Dry Type[b]		Semimoist[c]		Canned or Wet High Fat, Meat[d]		Canned or Wet Low Fat, Low Meat[e]	
kg	lb	(kcal/day)	g/kg body wt	kg/dog	g/kg body wt	kg/dog	g/kg body wt	kg/dog	g/kg body wt	kg/dog
2.3	5	247	33	0.07	38	0.09	83	0.19	119	0.27
4.5	10	408	27	0.12	32	0.14	70	0.31	101	0.45
6.8	15	556	25	0.17	29	0.20	63	0.43	91	0.62
9.1	20	692	23	0.21	27	0.24	58	0.53	84	0.77
13.6	30	935	21	0.28	24	0.33	53	0.72	76	1.04
22.7	50	1,373	18	0.42	21	0.49	47	1.06	67	1.53
31.8	70	1,768	17	0.54	20	0.62	43	1.36	62	1.96
49.8	110	2,475	15	0.75	18	0.87	38	1.90	55	2.75

[a]Approximate requirements for growth may be estimated by multiplying maintenance requirements by 2. If ME values of a particular food vary from those used in these calculations, the estimated food requirement in the table will vary accordingly. Dogs of different breeds, temperament, and physical condition utilize foods with differing degrees of effectiveness. Therefore, these requirements will vary with individual dogs in different environments and stress conditions. Working or lactating adult dogs may require 2–3 times more food than is required for maintenance.

[b]Assumed for purposed of calculation that this diet contained 90% dry matter, 24% crude protein, 10% fat, 46% starch and sugar and 10% fiber and ash. The apparent digestibility of crude protein was assumed to be 80%, fat 92%, starch and sugar 85%. Gross energy (GE) values used for protein, fat, and starch and sugar were 4.4 [5.65 – 1.25 (urinary losses)], 9.4 and 4.15 kcal/g, respectively. To calculate ME concentration, the above values were used as follows:

	Nutrient/Diet	Apparent Digestibility Coefficient	GE (kcal/g)	ME (kcal)
Crude protein	0.24	0.80	4.4	0.84
Fat	0.10	0.92	9.4	0.86
Starch and sugar	0.46	0.85	4.15	1.62
				3.32

Thus, the estimated ME concentration was 3.3 kcal/g.

[c]Assumed for purposes of calculation that this diet contained 75% dry matter, 20% crude protein, 8% crude fat, 34% starch and sugar, 8% fiber and ash and 5% propylene glycol. The same apparent digestibility and gross energy values were used as in footnote *b*, with the addition of an ME value of 4.7 kcal/g for propylene glycol (Weil, C. S., *et al.*, 1971. Results of feeding propylene glycol in the diet to dogs for two years. Food Cosmet. Toxicol. 9:479). The estimated ME concentration was 2.8 kcal/g.

[d]Assumed for purposes of calculation that this diet contained 25% dry matter, 9.2% crude protein, 11.0% fat, 1.2% starch and sugar and 3.6% fiber and ash. The apparent digestibility of crude protein was assumed to be 75%, fat 92%, and starch and sugar 85%. Gross energy values were as in footnote *b*. The estimated ME concentration was 1.3 kcal/g.

[e]Assumed for purposes of calculation that this diet was comparable in composition to dry-type dog food with water added and canned. Dry matter 25%. The estimated ME concentration was 0.9 kcal/g.

TABLE 5 Fat and Fatty Acid (FA) Composition of Feed Ingredients[a]

SCIENTIFIC NAME National Research Council Name (NRC) American Feed Control Name (AAFCO) Canada Feed Act Name (CFA) Other Names	International Reference Number	Dry Matter (%)	Ether Extract[b] (%)	Saturated Fat[c] (%)	Unsaturated Fat[c] (%)	Linoleic Acid[b] (%)
ALFALFA. *Medicago sativa*						
-aerial part, dehy grnd, mn 17% protein, (1)	1-00-023	93.0	2.5	33.6	66.4	0.43
-leaves, dehy grnd, mn 20% protein mx 18% fiber, (1)	1-00-136	93.1	3.1	26.1	73.9	0.56
ANIMAL						
-carcass residue, dry rendered, dehy grnd, mn 9% indigestible material mx 4.4% phosphorus, (5)	5-00-385	93.5	10.6	46.7	53.3	0.36
Meat meal (AAFCO)						
ANIMAL						
-carcass residue w blood, dry or wet rendered dehy grnd, mn 9% indigestible material mx 4.4% phosphorus, (5)	5-00-386	92.0	8.8	49.4	50.6	0.30
Meat meal tankage (AAFCO)						
Tankage, digester						
BARLEY. *Hordeum vulgare*						
-grain, (4)	4-00-530	89.0	2.1	29.6	70.4	0.27
BEEF TALLOW—see CATTLE						
CATTLE. *Bos spp*						
-whey, dehy, mn 65 lactose, (4)	4-01-182	94.0	0.9	63.6	36.4	0.01
Dried whey (AAFCO)						
-tallow, (4)	4-08-127	100.0	100.0	47.6	52.4	4.30
-milk skimmed dehy, mx 8% moisture, (5)	5-01-127	94.0	1.0	36.2	63.8	0.01
Dried skimmed milk, feed grade (AAFCO)						
COCONUT. *Cocos nucifera*						
-oil, (4)	4-09-320	100.0	100.0	90.3	9.7	1.10
CORN. *Zea mays*						
-grain, (4)	4-02-879	87.0	4.5	19.0	81.0	2.05
-oil, (4)	4-07-882	100.0	100.0	12.3	87.7	55.40
-distillers solubles, dehy, (5)	5-02-844	95.5	9.5	21.0	79.0	4.80
Corn distillers dried solubles (AAFCO)						
-gluten, wet milled dehy, (5)	5-02-900	91.0	8.4	18.0	82.0	4.21
Corn gluten meal (AAFCO)						
-yellow, grits by-product, mn 5% fat, (4)	4-03-011	90.5	7.2	16.0	84.0	3.71
Yellow hominy feed (AAFCO)						
CRAB. *Callinectes sapidus*						
-process residue, dehy grnd, mn 25% protein salt declared above 3% mx 7%, (5)	5-01-663	93.0	1.9	27.0	73.0	0.35
Crab meal (AAFCO)						
FISH						
-stickwater solubles, condensed, mn 30% protein, (5)	5-01-969	51.0	12.8	44.3	55.7	0.39
Condensed fish solubles (AAFCO)						
FISH, MENHADEN. *Brevoortia tyrannus*						
-menhaden, oil from whole fish, (7)	7-08-049	100.0	100.0	40.0	60.0	2.70
Menhaden oil (AAFCO)						
-whole or cuttings, cooked mech-extd dehy grnd, (5)	5-02-009	92.0	8.4	56.8	43.2	0.12
Fish meal, menhaden						
FLAX. *Linum usitatissimum*						
-oil, (4)	4-14-502	100.0	100.0	8.2	91.8	13.90
-seeds, solv extd grnd, mx 10% fiber, (5)	5-02-045	91.0	1.9	20.9	79.1	0.41
Linseed meal, solvent extracted (AAFCO)						
HOMINY FEED—see CORN, yellow						

TABLE 5 Fat and Fatty Acid (FA) Composition of Feed Ingredients[a] (*Continued*)

SCIENTIFIC NAME National Research Council Name (NRC) American Feed Control Name (AAFCO) Canada Feed Act Name (CFA) Other Names	International Reference Number	Dry Matter (%)	Ether Extract[b] (%)	Saturated Fat[c] (%)	Unsaturated Fat[c] (%)	Linoleic Acid[b] (%)
LARD—see SWINE						
LINSEED MEAL, solv extd—see FLAX						
LINSEED OIL—see FLAX						
MEAT MEAL—see ANIMAL						
MILO (sorghum grain)—see SORGHUM						
OATS. *Avena sativa*						
-grain, (4)	4-03-309	89.0	5.1	23.5	76.5	1.67
PEANUT. *Arachis hypogaea*						
-kernels, mech extd grnd, mx 7% fiber, (5)	5-03-649	92.0	7.3	23.9	76.1	1.36
Peanut meal, mechanical extracted (AAFCO)						
PECAN. *Caya illinoensis*						
-oil, (4)	4-14-503	100.0	100.0	6.9	93.1	30.60
POULTRY						
-viscera w feet w heads, dry or wet rendered dehy grnd, mx 16% ash 4% acid insoluble ash, (5)	5-03-798	93.4	12.5	36.0	64.0	1.98
Poultry by-product meal (AAFCO)						
-offal fat, (4)	4-09-319	100.0	100.0	39.1	60.9	22.30
RICE. *Oryza sativa*						
-oil from bran	4-14-504	100.0	100.0	18.5	81.5	36.50
SAFFLOWER. *Carthamus tinctorius*						
-oil, (4)	4-14-505	100.0	100.0	10.5	89.5	72.70
SKIM MILK—see CATTLE						
SORGHUM, MILO. *Sorghum vulgare*						
-grain, (4)	4-04-383	89.0	3.2	21.0	79.0	1.20
SOYBEANS. *Glycine max*						
-seeds, (5)	5-04-610	90.9	20.0	16.4	83.6	8.66
-flour by-product, grnd, mn 13% protein mx 32% fiber, (5)	5-04-594	89.4	6.8	19.5	80.5	3.29
Soybean mill feed (AAFCO)						
-seeds, solv extd grnd, mx 7% fiber, (5)	5-04-604	89.0	1.1	27.6	72.4	0.61
Soybean meal, solvent extracted 44% protein						
-seeds wo hulls, solv extd grnd, mx 3% fiber, (5)	5-04-612	89.8	0.9	28.8	71.2	0.39
Soybean meal, solvent extracted 49% protein						
SWINE. *Sus scrofa*						
-lard, (4)	4-04-790	100.0	100.0	35.9	64.1	18.30
TANKAGE, DIGESTER—see ANIMAL						
WHEAT. *Triticum* spp						
-bran, dry milled, (4)	4-05-190	89.0	4.6	20.3	79.7	2.53
-grain, (4)	4-05-211	89.0	1.9	21.4	78.6	0.65
-flour by-product, mx 9.5% fiber, (4)	4-05-205	88.9	5.2	20.2	79.8	2.79
Wheat middlings (AAFCO)						
WHEY, DEHY—see CATTLE						
YEAST. *Saccharomyces cerevisiae*						
-brewers saccharomyces, dehy grnd, mn 40% protein, (7)	7-05-527	93.0	1.1	22.7	77.3	0.05
Brewers dried yeast (AAFCO)						

[a]Data adapted from Edwards (1964).
[b]Expressed as percent (by weight) of the ingredient on a dry basis (100% dry matter).
[c]Expressed as percent (by weight) of the total fatty acids in the ingredient as fed. Fatty acids comprise about 95% of the weight of triglycerides, assuming the average triglyceride contains one glycerol, one 16-carbon fatty acid and two 18-carbon fatty acids.

TABLE 6 Composition of Some Common Dog Food Ingredients, Excluding Amino Acids

Line Number	SCIENTIFIC NAME National Research Council Name (NRC) American Feed Control Name (AAFCO) Canada Feed Act Name (CFA) Other Names	International Reference Number	Dry Matter (%)	Dry Basis ME (kcal/g)	Protein (%)	Ether Extract (%)	Crude Fiber (%)	Nitrogen-Free Extract (%)	Calcium (%)	Copper (mg/kg)	Iodine (mg/kg)	Iron (%)	Magnesium (%)	Manganese (mg/kg)	Phosphorus (%)
1	ALFALFA. *Medicago sativa*														
2	-aerial part, dehy grnd, mn 15% protein, (1)	1-00-022	93.1	2.34	16.3	2.5	28.4	43.8	1.32	11.2	.129	.033	.31	31.1	.24
3	-aerial part, dehy grnd, mn 17% protein, (1)	1-00-023	93.0	2.43	19.2	3.2	26.1	41.8	1.43	10.6	.161	.049	.31	31.2	.26
4	-aerial part, dehy grnd, mn 20% protein, (1)	1-00-024	93.1	2.57	22.1	3.9	21.7	41.2	1.63	11.4	.150	.043	.38	36.5	.29
5	ANIMAL. Scientific name not used														
6	-blood, dehy grnd, (5)	5-00-380	91.0	3.36	87.8	1.8	1.1	3.1	.31	10.9	–	.413	.24	5.8	.24
7	Blood meal (AAFCO)														
8	Blood meal (CFA)														
9	-blood, spray dehy, (5)	5-00-381	91.0	3.35	90.3	1.1	1.1	2.2	.49	8.9	–	.330	.04	7.0	.41
10	Blood flour														
11	-carcass residue, dry rendered dehy														
12	grnd, mx 4.4% phosphorus, (5)	5-00-385	93.5	3.02	57.1	10.6	2.6	2.8	8.49	10.4	–	.047	.29	10.2	4.31
13	Meat meal (AAFCO)														
14	Meat scrap														
15	-carcass residue w blood, dry or wet														
16	rendered dehy grnd, mx 4.4%														
17	phosphorus, (5)	5-00-386	92.0	3.07	65.0	8.8	2.2	.7	6.46	42.1	–	–	.17	20.8	3.44
18	Meat meal tankage														
19	Digester tankage														
20	-carcass residue w bone, dry rendered dehy														
21	grnd, mn 4.4% phosphorus, (5)	5-00-388	94.0	2.87	53.8	10.1	2.3	2.8	11.24	1.6	–	.053	1.20	13.1	5.39
22	Meat and bone meal (AAFCO)														
23	Meat and bone scrap														
24	-liver, dehy grnd, (5)	5-00-389	92.6	4.08	71.8	16.3	1.4	4.0	.54	96.4	–	.068	–	9.5	1.35
25	Animal liver meal (AAFCO)														
26	Animal liver meal (CFA)														
27	Liver meal														
28	-bone, steamed dehy grnd, (6)	6-00-400	95.0	–	12.7	3.4	2.1	–	30.51	17.2	–	.088	.67	32.0	14.30
29	Bone meal, steamed (AAFCO)														
30	-bone phosphate, precipitated dehy,														
31	mn 17% phosphorus, (6)	6-00-406	99.0	–	.4	.3	–	–	28.03	–	–		–	–	11.31
32	Bone phosphate (AAFCO)														
33	ANIMAL–POULTRY.														
34	-fat, heat rendered, mn 90% fatty acids														
35	mx 2.5% unsaponifiable matter														
36	mx 1% insoluble matter, (4)	4-00-409	99.5	8.65	–	99.5	–	–	–	–	–	–	–	–	–
37	Animal fat (AAFCO)														
38	BARLEY. *Hordeum vulgare*														
39	-grain, (4)	4-00-530	89.0	3.34	13.0	2.1	5.6	76.6	.09	8.6	–	.005	.13	18.3	.47
40	-grain, Pacific coast, (4)	4-07-939	89.0	3.32	10.9	2.5	7.0	77.0	.07	–	–	–	–	18.0	.45
41	-malt sprouts w hulls, dehy, mn 24%														
42	protein, (5)	5-00-545	93.0	2.83	28.2	1.5	15.1	48.3	.24	–	–	–	.19	34.1	.78
43	Malt sprouts (AAFCO)														
44	BEET, SUGAR. *Beta saccharifera*														
45	-molasses, mn 48% invert sugar mn 79.5														
46	degrees brix, (4)	4-00-668	77.0	3.17	8.7	.3	–	80.4	.21	22.9	–	.013	.30	6.0	.04
47	Beet molasses (AAFCO)														
48	Molasses (CFA)														
49	-pulp, dehy, (4)	4-00-669	91.0	2.69	10.0	.7	20.9	64.5	.74	13.7	–	.033	.30	38.5	.11
50	Dried beet pulp (AAFCO)														
51	Dried beet pulp (CFA)														
52	BLOOD–see ANIMAL														
53	BONE–see ANIMAL														
54	BREAD.														
55	-dehy, (4)	4-07-944	95.0	3.49	11.6	1.1	.5	84.8	.03	–	–	–	–	–	.10
56	BREWERS–see GRAINS														
57	BUTTERMILK–see CATTLE														
58	CALCIUM PHOSPHATE, DIBASIC														
59	-commercial, (6)	6-01-080	96.0	–	–	–	–	–	23.12	–	–	–	–	–	18.64
60	Dicalcium phosphate (AAFCO)														
61	CALCIUM–also see LIMESTONE														
62	Calcium Carbonate, $CaCO_3$														
63	-commercial mn 38%														
64	calcium, (6)	6-01-069	98.6	–	–	–	–	–	39.34	–	–	–	.06	–	.04
65	CASEIN–see CATTLE														
66	CATTLE. *Bos spp*														
67	-whey, dehy, mn 65% lactose, (4)	4-01-182	94.0	3.21	14.7	.9	.0	74.1	.93	45.9	–	.017	.14	.49	.84
68	Dried whey (AAFCO)														
69	Whey, dried														
70	-whey low lactose, dehy, mn														
71	lactose, declared, (4)	4-01-186	91.0	3.04	17.3	1.4	.2	65.4	1.70	–	–	–	–	–	1.09
72	Dried whey-product (AAFCO)														
73	-buttermilk, condensed, mn 27% total														
74	solids w mn 0.055% fat mx 0.14% ash														
75	per 1% solids, (5)	5-01-159	29.0	3.54	36.7	8.6	–	42.6	1.52	–	–	–	.66	–	.90
76	Condensed buttermilk (AAFCO)														
77	Buttermilk, concentrated														
78	Buttermilk, condensed														
79	Buttermilk, evaporated														
80	-buttermilk, dehy, feed gr mx 8% moisture														
81	mx 13% ash mn 5% fat, (5)	5-01-160	93.0	3.46	34.4	6.2	.0	48.6	1.44	–	–	–	.41	3.8	1.01
82	Dried buttermilk, feed grade (AAFCO)														
83	Buttermilk, dried														
84	-casein, milk acid precipitated dehy,														
85	mn 80% protein, (5)	5-01-162	90.0	3.42	90.9	.6	.0	4.8	.68	–	–	–	–	4.9	1.10

(1) dry forages and roughages; (2) pasture, range plants, and forages fed green; (3) silages;

Line Number	Dry Basis Potassium (%)	Sodium (%)	Zinc (mg/kg)	Biotin (mg/kg)	Choline (mg/kg)	Folic acid (mg/kg)	Niacin (mg/kg)	Pantothenic acid (mg/kg)	Provitamin A (Carotene) (mg/kg)	Pyridoxine (mg/kg)	Riboflavin (mg/kg)	Thiamin (mg/kg)	Vitamin B_{12} (µg/kg)	Vitamin E (mg/kg)	Vitamin K (mg/kg)
1															
2	2.50	.08	21.5	–	1665.	1.65	45.0	22.4	109.5	6.98	11.4	3.2	–	105.3	10.63
3	2.67	.10	17.2	.35	1632.	2.26	49.2	32.2	108.8	6.77	13.2	3.5	–	137.6	9.35
4	2.71	.92	19.3	–	1738.	2.87	58.7	35.2	232.4	–	16.6	4.2	–	–	–
5															
6	.99	.35	–	–	832.	–	34.6	1.2	–	–	1.6	–	–	.0	–
7															
8															
9	.45	.36	–	–	306.	–	31.4	5.8	–	–	4.6	.4	–	–	–
10															
11															
12	.59	1.80	–	.10	2091.	.05	60.8	5.1	–	3.21	5.7	.2	54.7	1.1	–
13															
14															
15															
16															
17	.61	1.82	–	–	2358.	1.63	42.6	2.8	–	–	2.6	–	–	–	–
18															
19															
20															
21	1.55	.78	104.2	.15	2329.	.05	50.8	3.9	–	2.65	4.7	1.2	47.6	1.1	–
22															
23															
24	–	–	–	.02	–	6.00	220.0	48.8	–	–	50.0	.2	541.6	–	–
25															
26															
27															
28	–	.48	446.9	–	–	–	4.4	2.5	–	–	.9	.4	–	–	–
29															
30															
31	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
32															
33															
34															
35															
36	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
37															
38															
39	.63	.02	17.2	.22	1157.	.56	64.5	7.3	–	3.26	2.2	5.7	–	6.8	–
40	.56	.02	16.8	.17	1053.	.56	49.6	8.2	–	3.26	4.8	4.5	–	40.4	–
41															
42	.22	–	–	–	1703.	.22	46.6	9.2	–	–	1.6	.8	–	–	–
43															
44															
45															
46	6.19	1.52	–	–	–	–	54.8	6.0	–	–	3.1	–	–	–	–
47															
48															
49	.23	–	.8	–	911.	–	17.9	1.6	–	–	.8	.4	–	–	–
50															
51															
52															
53															
54															
55	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
56															
57															
58															
59	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
60															
61															
62															
63															
64															
65															
66															
67	1.28	.51	–	.42	21.	.96	11.9	50.7	–	2.66	31.8	3.9	.03	–	–
68	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
69															
70															
71	–	–	–	–	1944.	–	65.8	75.8	–	–	61.0	–	–	–	–
72															
73															
74															
75	.79	1.07	–	–	–	–	–	–	–	–	49.3	–	–	–	–
76															
77															
78															
79															
80															
81	.76	1.02	–	.32	1944.	.43	9.2	32.4	–	2.58	33.3	3.8	.02	6.8	–
82															
83															
84															
85	–	–	–	–	232.	.44	1.4	2.9	–	.44	1.7	.4	–	–	–

(4) energy feeds; (5) protein supplements; (6) minerals; (7) vitamins; (8) additives.

TABLE 6 Composition of Some Common Dog Food Ingredients, Excluding Amino Acids (*Continued*)

				Dry Basis											
Line Number	SCIENTIFIC NAME National Research Council Name (NRC) American Feed Control Name (AAFCO) Canada Feed Act Name (CFA) Other Names	International Reference Number	Dry Matter (%)	ME (kcal/g)	Protein (%)	Ether Extract (%)	Crude Fiber (%)	Nitrogen-Free Extract (%)	Calcium (%)	Copper (mg/kg)	Iodine (mg/kg)	Iron (%)	Magnesium (%)	Manganese (mg/kg)	Phosphorus (%)
86	Casein (AAFCO)														
87	Casein, dried														
88	-lips, raw, (5)	5-07-940	30.0	–	60.0	23.3	–	–	–	–	–	–	–	–	–
89	-liver, raw, (5)	5-01-166	27.2	3.99	73.6	12.5	.0	9.1	.04	–	–	–	–	–	.88
90	Beef liver														
91	-lungs, raw, (5)	5-07-941	20.0	–	80.0	15.0	–	–	–	–	–	–	–	–	–
92	-milk, dehy, feed gr mx 8% moisture														
93	mn 26% fat, (5)	5-01-167	93.7	4.76	26.9	28.2	.2	38.9	.95	–	–	.018	–	.4	.72
94	Dried whole milk (AAFCO)														
95	Milk, whole, dried														
96	-milk, skimmed dehy, mx 8% moisture, (5)	5-01-175	94.0	3.28	35.6	1.0	.2	55.1	1.34	12.2	–	.005	.12	2.3	1.10
97	Dried skimmed milk, feed grade (AAFCO)														
98	Milk, skimmed, dried														
99	-spleen, raw, (5)	5-07-942	25.0	3.92	72.0	16.0	–	–	–	–	–	–	–	–	–
100	Cattle, melts, raw														
101	-udders, raw, (5)	5-07-943	25.0	5.74	48.0	48.0	–	–	–	–	–	–	–	–	–
102	CHICKEN. *Gallus domesticus*														
103	-broilers, whole, raw, (5)	5-07-945	24.3	4.27	76.5	20.2	–	–	–	–	–	–	–	–	–
104	-cull hens, whole, raw, (5)	5-07-950	57.9	3.95	27.6	35.2	.9	–	–	–	–	–	–	–	–
105	-day-old chicks, whole, raw, (5)	5-07-946	24.4	4.04	57.0	23.5	3.6	–	–	–	–	–	–	–	–
106	-eggs w shells, raw, (5)	5-01-213	34.1	4.01	37.5	31.1	.0	.0	4.40	–	–	–	–	–	–
107	-feet, raw, (5)	5-07-947	47.0	3.15	53.2	23.4	–	–	–	–	–	–	–	–	–
108	-gizzards, raw, (5)	5-07-948	25.0	5.14	80.4	10.5	.0	2.8	–	–	–	–	–	–	–
109	-heads, raw, (5)	5-07-949	33.0	3.47	57.6	18.2	–	–	–	–	–	–	–	–	–
110	-offal w feet, raw, (5)	5-07-951	31.0	4.64	42.3	41.6	–	–	2.64	–	–	–	–	–	1.35
111	-offal wo feet, raw, (5)	5-07-952	27.0	5.09	43.7	42.2	.7	–	1.00	–	–	–	–	–	.70
112	CITRUS. *Citrus* spp														
113	-pulp wo fines, shredded dehy, (4)	4-01-237	90.0	3.04	7.3	5.1	14.4	66.5	2.18	6.3	–	.018	.18	7.6	.13
114	Dried citrus pulp (AAFCO)														
115	Citrus pulp, dried														
116	COCONUT. *Cocos nucifera*														
117	-meats, mech-extd grnd, (5)	5-01-572	93.0	3.17	21.9	7.1	12.9	50.7	.23	20.1	–	.211	.28	59.6	.66
118	Coconut meal, mechanical extracted (AAFCO)														
119	Copra meal, expeller (AAFCO)														
120	Coconut meal, hydraulic														
121	Copra meal, hydraulic														
122	-meats, solv-extd grnd, (5)	5-01-573	92.0	2.83	22.9	2.0	16.1	52.5	.18	–	–	–	–	59.8	.66
123	Coconut meal, solvent extracted (AAFCO)														
124	Solvent extracted copra meal (AAFCO)														
125	CORN. *Zea mays*														
126	-grain, flaked, (4)	4-02-859	97.0	3.20	8.0	.3	.4	82.0	.01	–	–	–	–	–	.04
127	Flaked corn (AAFCO)														
128	Corn grain, flaked														
129	-grits byproduct, mn 5% fat, (4)	4-02-887	90.6	3.60	11.8	7.2	5.5	72.7	.06	16.1	–	.007	.26	16.1	.58
130	Hominy feed (AAFCO)														
131	Hominy feed (CFA)														
132	-distillers grains w solubles, dehy,														
133	mn 75% original solids, (5)	5-02-843	91.0	3.48	29.7	8.8	9.3	47.5	.38	54.9	.05	.022	.38	33.0	1.04
134	Corn distillers dried grains with														
135	solubles (AAFCO)														
136	-distillers solubles, dehy, (5)	5-02-844	95.5	3.57	29.8	9.4	4.2	48.4	.31	57.6	.05	.021	.62	62.8	1.68
137	Corn distillers dried solubles (AAFCO)														
138	-germ wo solubles, wet milled solv-extd														
139	dehy grnd, (5)	5-02-898	93.0	3.07	19.4	2.2	12.9	62.2	.11	–	–	–	–	17.2	.43
140	Corn germ meal, solvent extracted,														
141	(wet milled) (AAFCO)														
142	-gluten, wet milled dehy, (5)	5-02-900	91.0	3.40	47.1	2.5	4.4	43.4	.18	31.0	–	.044	.05	8.0	.44
143	Corn gluten meal (AAFCO)														
144	Corn gluten meal (CFA)														
145	CORN, DENT YELLOW. *Zea mays indentata*														
146	-grain, (4)	4-02-935	86.0	3.62	10.2	4.4	2.3	81.8	.03	4.0	–	.003	.17	4.8	.31
147	-grain, grnd cooked, (4)	4-07-953	88.0	3.60	10.5	4.5	2.4	80.6	.02	–	–	–	–	–	.30
148	CORN, FLINT. *Zea mays indurata*														
149	-grain, (4)	4-02-948	89.0	3.64	11.1	4.8	2.2	80.3	–	13.0	–	.003	–	7.9	.24
150	CORN, WHITE. *Zea mays*														
151	-grits by-prod, mn 5% fat, (4)	4-02-990	89.9	3.53	12.0	6.3	5.2	72.7	.06	–	–	–	–	–	1.10
152	White hominy feed (AAFCO)														
153	White hominy feed (CFA)														
154	Hominy, white corn, feed														
155	Corn, white, hominy feed														
156	COTTON. *Gossypium* spp														
157	-seed w some hulls, mech-extd grnd, mn 41%														
158	protein mx 14% fiber mn 2% fat, (5)	5-01-617	94.0	3.08	43.6	4.6	12.8	32.4	.17	20.7	–	.032	.60	22.9	1.28
159	Cottonseed meal, 41% protein														
160	-seed w some hulls, pre-press solv-extd														
161	grnd, 41% protein, (5)	5-07-872	92.5	2.88	43.6	1.5	12.7	34.5	.17	20.7	–	.032	.60	22.9	1.28
162	Cottonseed meal, pre-press solvent														
163	extracted, 41% protein														
164	-seed w some hulls, solv-extd grnd, mn 41%														
165	protein mx 14% fiber mn 0.5% fat, (5)	5-01-621	91.5	2.94	44.8	2.2	13.1	33.1	.17	21.3	–	.033	.61	23.5	1.31
166	Cottonseed meal, solvent extracted,														
167	41% protein														
168	-seed wo hulls, pre-press solv-extd grnd,														
169	mn 50% protein, (5)	5-07-874	92.5	3.03	54.0	1.3	9.2	28.8	.17	19.4	–	.012	.50	24.6	1.09
170	Cottonseed meal, pre-press solvent														
171	extracted, 50% protein														

(1) dry forages and roughages; (2) pasture, range plants, and forages fed green; (3) silages;

Line Number	Dry Basis Potassium (%)	Sodium (%)	Zinc (mg/kg)	Biotin (mg/kg)	Choline (mg/kg)	Folic acid (mg/kg)	Niacin (mg/kg)	Pantothenic acid (mg/kg)	Provitamin A (Carotene) (mg/kg)	Pyridoxine (mg/kg)	Riboflavin (mg/kg)	Thiamin (mg/kg)	Vitamin B_{12} (µg/kg)	Vitamin E (mg/kg)	Vitamin K (mg/kg)
86															
87															
88	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
89	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
90															
91															
92															
93	1.08	.38	–	.39	–	–	9.0	24.2	7.5	4.94	20.9	3.9	–	–	–
94															
95															
96	1.78	.53	42.6	3.5	1517.	.66	12.2	35.8	–	4.22	21.4	3.7	44.57	9.8	–
97															
98															
99	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
100															
101	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
102															
103	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
104	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
105	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
106	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
107	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
108	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
109	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
110	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
111	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
112															
113	.69	–	16.1	–	939.	–	24.0	14.4	–	–	2.7	1.7	–	–	–
114															
115															
116															
117	1.20	.04	–	–	989.	1.40	26.8	7.1	–	–	3.3	.8	–	–	–
118															
119															
120															
121															
122	–	.04	–	–	1196.	.33	26.0	7.2	–	4.78	14.3	1.0	–	–	–
123															
124															
125															
126	–	–	–	–	–	–	21.6	–	–	–	1.3	4.2	–	–	–
127															
128															
129	.74	.44	–	.14	1104.	.31	56.4	8.3	10.1	12.14	2.2	8.7	–	–	–
130															
131															
132															
133	1.10	.05	87.9	.33	3700.	1.10	84.6	12.1	4.0	7.10	9.9	3.8	1.60	43.4	–
134															
135															
136	2.20	.16	104.7	.52	6100.	1.80	125.6	23.0	.8	13.60	23.0	7.3	7.00	59.1	–
137															
138															
139	.22	–	–	3.22	1935.	.22	37.7	4.4	–	–	4.4	1.1	–	93.5	–
140															
141															
142	.03	.11	–	.16	363.	.22	54.8	11.3	–	8.79	1.6	.2	–	46.2	–
143															
144															
145															
146	.38	.01	12.1	.07	624.	.22	26.6	5.8	4.8	8.37	1.3	4.6	–	25.6	–
147	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
148															
149	–	–	–	–	–	–	17.8	–	–	–	–	–	–	–	–
150															
151	–	–	–	–	–	–	61.5	7.5	–	–	2.4	14.6	–	–	–
152															
153															
154															
155															
156															
157															
158	1.49	.04	–	–	2957.	2.45	42.0	14.9	–	5.64	5.3	6.9	–	42.6	–
159															
160															
161	1.49	.04	–	–	3042.	2.45	42.0	14.9	–	–	5.3	6.9	–	–	–
162															
163															
164															
165	1.53	.04	–	.11	3126.	2.51	43.2	15.3	–	6.99	5.5	7.1	–	16.4	–
166															
167															
168															
169	1.36	.05	79.2	.11	3568.	1.19	55.1	16.2	–	7.57	6.2	–	–	16.2	–
170															
171															

(4) energy feeds; (5) protein supplements; (6) minerals; (7) vitamins; (8) additives.

TABLE 6 Composition of Some Common Dog Food Ingredients, Excluding Amino Acids (*Continued*)

				Dry Basis											
Line Number	SCIENTIFIC NAME / National Research Council Name (NRC) / American Feed Control Name (AAFCO) / Canada Feed Act Name (CFA) / Other Names	International Reference Number	Dry Matter (%)	ME (kcal/g)	Protein (%)	Ether Extract (%)	Crude Fiber (%)	Nitrogen-Free Extract (%)	Calcium (%)	Copper (mg/kg)	Iodine (mg/kg)	Iron (%)	Magnesium (%)	Manganese (mg/kg)	Phosphorus (%)
172	CRAB. *Callinectes sapidus, Cancer* spp														
173	*Paralithodes canschatica*														
174	-processed residue, dehy grnd, mn 25%														
175	protein salt declared above 3%														
176	mx 7%, (5)	5-01-663	93.0	1.62	33.4	1.9	11.8	9.1	16.47	35.3	–	.473	.95	143.9	1.71
177	Crab meal (AAFCO)														
178	DISTILLERS—see CORN														
179	FAT—see ANIMAL														
180	FISH.														
181	-livers, extn unspecified dehy grnd,														
182	salt declared above 4%, (5)	5-01-968	93.0	4.17	71.5	16.8	1.1	5.8	.54	96.8	–	.075	–	9.5	1.34
183	Fish liver meal (CFA)														
184	-soluble, condensed, mn 30% protein, (5)	5-01-969	51.0	3.41	61.6	12.7	2.0	4.1	1.20	94.5	–	.059	.04	23.3	1.37
185	Condensed fish solubles (AAFCO)														
186	-stickwater soluble, cooked dehy, mn														
187	60% protein, (5)	5-01-971	92.0	3.30	68.3	8.3	1.1	5.1	–	–	–	–	–	–	–
188	Dried fish solubles (AAFCO)														
189	Fish solubles, dried														
190	FISH, ALEWIFE. *Pomolobus pseudoharengus*														
191	-whole, raw, (5)	5-07-964	26.0	4.30	75.0	19.2	–	–	–	–	–	–	–	–	–
192	-whole or cuttings, cooked mech-extd														
193	dehy grnd, (5)	5-09-830	91.0	2.07	62.6	–	–	–	–	–	–	–	–	–	–
194	Fish meal, alewife														
195	FISH, ANCHOVY. *Engraulis* spp														
196	-whole or cuttings, cooked mech-extd														
197	dehy grnd, (5)	5-01-985	93.0	2.84	70.9	5.8	1.1	–	4.84	–	–	–	–	23.6	3.06
198	Fish meal, anchovy														
199	FISH, CARP. *Cyprinus carpio*														
200	-whole, raw, (5)	5-01-986	22.0	3.86	84.1	10.4	–	–	–	–	–	–	–	–	–
201	-whole or cuttings, cooked dehy grnd, (5)	5-09-831	90.8	2.46	74.4	–	.8	–	–	–	–	–	–	–	–
202	Fish meal, carp														
203	FISH, CATFISH. *Ictalurus* spp														
204	-whole, raw, (5)	5-07-985	17.5	3.52	94.3	2.3	–	–	–	–	–	–	–	–	–
205	-whole or cuttings, cooked mech-extd dehy														
206	grnd, (5)	5-09-835	93.9	1.82	56.3	–	–	–	7.77	27.7	–	–	–	–	–
207	Fish meal, catfish														
208	-whole or cuttings, cooked mech-extd														
209	press cake, (5)	5-09-834	47.1	1.73	52.4	–	–	–	–	–	–	.040	.18	40.4	4.04
210	-whole or cuttings, cooked pasteurized, (5)	5-09-833	39.9	2.45	68.7	–	–	–	–	7.5	–	.050	1.25	16.0	2.43
211	-whole or cuttings, raw, (5)	5-09-832	42.2	2.27	64.5	–	–	–	5.57	7.1	–	.009	.12	10.6	2.55
212	FISH, FLOUNDER. Bothidae (family),														
213	Pleuronectidae (family)														
214	-whole, raw, (5)	5-01-996	17.0	3.38	88.2	2.9	–	–	–	–	–	–	–	–	–
215	FISH, HADDOCK. *Melanogrammus aeglefinus*														
216	-whole, raw, (5)	5-07-966	18.0	3.47	94.4	1.7	–	–	–	–	–	–	–	–	–
217	FISH, HAKE, *Merluccius* spp. *Urophycis* spp														
218	-whole, cooked (5)	5-07-967	30.0	3.65	57.4	18.8	–	–	–	–	–	–	–	–	–
219	-whole, cooked acidified, (5)	5-07-968	25.0	–	–	21.2	1.1	–	–	–	–	–	–	–	–
220	-whole, raw, (5)	5-07-969	19.0	3.65	89.5	5.8	–	–	–	–	–	–	–	–	–
221	FISH, HERRING. *Clupea harengus harengus,*														
222	*Clupea harengus pallasi*														
223	-whole, raw, (5)	5-01-999	26.0	4.26	69.2	21.1	–	–	–	–	–	–	–	–	–
224	-whole or cuttings, cooked mech-extd														
225	dehy grnd, (5)	5-02-000	92.0	3.38	76.7	8.2	1.1	3.4	3.20	–	–	–	–	10.8	2.39
226	Fish meal, herring														
227	FISH, MACKEREL ATLANTIC. *Scomber scombrus*														
228	-whole, raw, (5)	5-07-971	32.0	5.28	57.8	37.5	–	–	–	–	–	–	–	–	–
229	FISH, MACKEREL PACIFIC. *Scomber japonicus*														
230	-whole, raw, (5)	5-07-972	31.0	4.82	71.0	24.5	–	–	–	–	–	–	–	–	–
231	FISH, MENHADEN. *Brevoortia tyrannus*														
232	-whole or cuttings, cooked mech-extd														
233	dehy grnd, (5)	5-02-009	92.0	3.02	66.6	8.4	1.1	2.6	5.97	9.1	–	.061	–	27.9	3.06
234	Fish meal, menhaden														
235	FISH, REDFISH. *Sciaenops ocellata*														
236	-whole, raw, (5)	5-08-113	19.8	3.37	90.9	2.0	–	.6	–	–	–	–	–	–	–
237	Drumfish, whole, raw														
238	Ocean perch, whole, raw														
239	-whole or cuttings, cooked mech-extd dehy grnd, (5)	5-07-973	94.2	2.66	58.4	8.5	1.1	–	4.20	–	–	–	–	–	2.40
240	Fish meal, drum														
241	Fish meal, redfish														
242	FISH, ROCKFISH. *Sebastodes* spp														
243	-whole, raw, (5)	5-07-974	32.0	3.74	50.7	22.6	–	–	–	–	–	–	–	–	–
244	FISH, SALMON. *Oncorhynchus* spp. *Salmo* spp														
245	-whole, raw, (5)	5-02-011	35.0	5.42	62.8	37.1	–	–	–	–	–	–	–	–	–
246	-whole or cuttings, cooked mech-extd														
247	dehy grnd, (5)	5-02-012	93.0	3.20	62.4	10.4	–	6.8	5.85	12.8	–	.020	–	7.9	3.26
248	Fish meal, salmon														
249	FISH, SARDINE. *Clupea* spp, *Sardinops* spp														
250	-whole or cuttings, cooked mech-extd														
251	dehy grnd, (5)	5-02-015	93.0	2.97	70.4	4.6	1.1	7.0	5.27	21.7	–	.032	.11	23.9	2.98
252	FISH, SMELT. *Asmerus* spp														
253	-whole, raw, (5)	5-07-975	21.0	3.76	85.7	8.6	–	–	–	–	–	–	–	–	–
254	FISH, SOLE. Soleidae (family)														
255	-whole, raw, (5)	5-07-976	19.0	3.33	72.3	9.1	–	–	3.32	–	–	–	–	–	2.30
256	FISH, TUNA. *Thunnus thynnus*														
257	-process residue, (5)	5-07-977	44.0	3.89	54.8	21.8	–	–	–	–	–	–	–	–	–

(1) dry forages and roughages; (2) pasture, range plants, and forages fed green; (3) silages;

Line Number	Dry Basis Potassium (%)	Sodium (%)	Zinc (mg/kg)	Biotin (mg/kg)	Choline (mg/kg)	Folic acid (mg/kg)	Niacin (mg/kg)	Pantothenic acid (mg/kg)	Provitamin A (Carotene) (mg/kg)	Pyridoxine (mg/kg)	Riboflavin (mg/kg)	Thiamin (mg/kg)	Vitamin B_{12} (μg/kg)	Vitamin E (mg/kg)	Vitamin K (mg/kg)
172															
173															
174															
175															
176	.48	.91	–	–	2150.	–	47.3	6.1	–	–	6.3	–	–	–	–
177															
178															
179															
180															
181															
182	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
183															
184	3.43	6.00	75.1	.39	7898.	–	330.8	69.4	–	–	28.4	10.8	–	–	–
185															
186															
187	–	–	–	–	5677.	–	251.2	48.8	–	–	8.4	–	–	–	–
188															
189															
190															
191	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
192															
193	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
194															
195															
196															
197	.54	.86	118.2	.39	3978.	.22	68.8	9.46	–	3.76	7.1	–	.11	3.6	–
198															
199															
200	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
201	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
202															
203															
204	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
205															
206	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
207															
208															
209	.58	.65	121.4	–	–	–	–	–	–	–	–	–	–	–	–
210	.45	.50	90.2	–	–	–	–	–	–	–	–	–	–	–	–
211	.25	.34	67.9	–	–	–	–	–	–	–	–	–	–	–	–
212															
213															
214	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
215															
216	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
217															
218	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
219	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
220	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
221															
222															
223	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
224															
225	.54	.54	–	.46	4352.	2.61	96.6	12.4	–	4.02	9.8	–	237.70	29.3	.00
226															
227															
228	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
229															
230	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
231															
232															
233	.76	.33	163.0	.28	3348.	.22	60.8	9.6	–	–	5.2	.8	.11	9.8	–
234															
235															
236	1.36	.30	–	–	–	–	176.8	–	–	–	2.5	7.6	–	–	–
237															
238															
239	–	–	–	–	1486.	–	28.7	2.6	–	–	3.1	–	–	–	–
240															
241															
242															
243	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
244															
245	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
246															
247	–	–	–	–	2772.	–	24.9	6.8	–	–	5.7	.9	–	–	–
248															
249															
250															
251	.35	.19	–	–	3182.	–	66.7	9.9	–	–	6.3	.4	–	–	–
252															
253	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
254															
255	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
256															
257	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–

(4) energy feeds; (5) protein supplements; (6) minerals; (7) vitamins; (8) additives.

TABLE 6 Composition of Some Common Dog Food Ingredients, Excluding Amino Acids (*Continued*)

Line Number	SCIENTIFIC NAME National Research Council Name (NRC) American Feed Control Name (AAFCO) Canada Feed Act Name (CFA) Other Names	International Reference Number	Dry Matter (%)	Dry Basis ME (kcal/g)	Protein (%)	Ether Extract (%)	Crude Fiber (%)	Nitrogen-Free Extract (%)	Calcium (%)	Copper (mg/kg)	Iodine (mg/kg)	Iron (%)	Magnesium (%)	Manganese (mg/kg)	Phosphorus (%)
258	-whole or cuttings, cooked mech-extd														
259	dehy grnd, (5)	5-02-023	87.0	2.82	65.9	7.5	1.1	3.6	6.11	–	–	–	–	–	3.53
260	Fish meal, tuna														
261	FISH, TURBOT. *Psetta maxima*														
262	-whole, raw, (5)	5-07-978	27.0	5.22	53.2	38.7	–	–	1.46	–	–	–	–	–	1.17
263	FISH, WHITE. Gadidae (family), Lophiidae (family),														
264	Rajidae (family)														
265	-whole or cuttings, cooked mech-extd														
266	dehy grnd, mx 4% oil, (5)	5-02-025	92.0	2.90	68.7	4.8	1.1	1.8	8.55	–	–	–	–	15.5	3.92
267	White fish meal (CFA)														
268	Fish, cod, meal														
269	Fish, cusk, meal														
270	Fish, haddock, meal														
271	Fish, hake, meal														
272	Fish, pollock, meal														
273	Fish, monkfish, meal														
274	Fish, skate, meal														
275	FISH, WHITING. *Gadus merlangus*														
276	-whole, raw, (5)	5-07-979	23.0	3.21	69.9	8.7	–	–	–	–	–	–	–	–	–
277	FLAX. *Linum usitatissimum*														
278	-seed, mech-extd grnd, mx 0.5% acid														
279	insoluble ash, (5)	5-02-045	91.0	3.25	38.8	5.7	9.9	39.4	.48	29.0	–	.019	.64	43.3	9.8
280	Linseed meal, mechanical extracted (AAFCO)														
281	Linseed meal (CFA)														
282	Linseed oil meal, expeller extracted														
283	Linseed oil meal, hydraulic extracted														
284	Linseed meal, old process														
285	-seed screenings, mech-extd grnd, (5)	5-02-054	91.0	3.33	17.4	10.3	13.2	51.7	.41	–	–	–	–	–	.47
286	Flaxseed screenings meal (AAFCO)														
287	-seed, solv-extd grnd, mx 0.5% acid														
288	insoluble ash, (5)	5-02-048	91.0	3.05	38.6	1.9	9.9	43.2	.44	28.2	–	.036	.66	41.3	.91
289	Linseed meal, solvent extracted (AAFCO)														
290	Solvent extracted linseed meal (CFA)														
291	Linseed oil meal, solvent extracted														
292	GRAINS.														
293	-brewers grains, dehy, mx 3% dried														
294	spent hops, (5)	5-02-141	92.0	3.16	28.2	6.7	16.3	45.0	.29	23.2	–	.027	.15	40.9	.54
295	Brewers dried grains (AAFCO)														
296	Brewers dried grains (CFA)														
297	-distillers grains, dehy, (5)	5-02-144	92.5	3.24	29.2	8.2	13.8	42.5	.05	16.2	.05	.014	.08	10.8	.40
298	HOMINY FEED—see CORN														
299	HORSE. *Equus caballus*														
300	-meat, raw, (5)	5-07-980	24.0	4.08	75.0	16.7	–	–	.13	–	–	–	–	–	1.69
301	-meat w bone, raw grnd, (5)	5-07-981	36.0	3.49	51.4	19.4	–	–	–	–	–	–	–	–	–
302	LARD—see SWINE														
303	LIMESTONE.														
304	-grnd, mn 33% calcium, (6)	6-02-632	100.0	–	–	–	–	–	33.84	–	–	.330	–	275.6	.02
305	Limestone, ground (AAFCO)														
306	LINSEED—see FLAX														
307	LIVER—see ANIMAL														
308	MAIZE—see CORN														
309	MALT—see BARLEY														
310	MEAT—see ANIMAL														
311	MILK—see CATTLE														
312	MILLET. *Setaria* spp														
313	-grain, (4)	4-03-098	90.0	3.31	13.3	4.4	8.9	69.9	.06	24.0	–	.004	.18	32.3	.31
314	MOLASSES—see BEET, SUGAR, see SUGARCANE														
315	OATS. *Avena sativa*														
316	-hulls, (1)	1-03-281	93.0	2.39	6.0	2.2	29.0	56.3	.17	5.5	–	.011	.09	19.9	.20
317	Oat hulls (AAFCO)														
318	Oat hulls (CFA)														
319	-cereal byproduct, mx 4% fiber, (4)	4-03-303	91.0	3.61	17.4	6.4	4.3	69.3	.09	–	–	.042	–	48.4	.54
320	Feeding oat meal (AAFCO)														
321	Oat middlings (CFA)														
322	-grain, (4)	4-03-309	89.0	3.22	13.2	5.1	12.4	65.7	.11	6.6	–	.008	.19	42.9	.39
323	-grain, gr 1 US mn wt 34 lb per bushel														
324	mx 2% foreign material, (4)	4-03-313	91.0	3.21	13.3	5.3	13.2	64.7	.09	–	–	–	–	41.8	.33
325	-grain, gr 2 heavy US mn wt 36 lb per														
326	bushel mx 3% foreign material, (4)	4-03-315	89.5	3.25	13.5	4.5	10.9	67.6	–	–	–	–	–	–	–
327	Oats, grain, heavy														
328	-grain, gr 2 US mn wt 32 lb per bushel														
329	mx 3% foreign material, (4)	4-03-316	89.0	3.21	12.7	4.7	12.4	66.9	.07	–	–	–	–	–	–
330	OATS. *Avena sativa*														
331	-grain, gr 3 US mn wt 30 lb per bushel														
332	mx 4% foreign material, (4)	4-03-317	91.0	3.15	13.3	5.1	14.3	63.6	–	–	–	–	–	–	–
333	-grain, gr 4 US mn wt 27 lb per bushel														
334	mx 5% foreign material, (4)	4-03-318	91.2	3.01	13.2	4.9	16.6	60.2	–	–	–	–	–	–	–
335	Oats, grain, light														
336	-groats, (4)	4-03-331	91.0	3.66	18.4	6.4	3.3	69.5	.08	0.4	–	–	.98	31.4	.47
337	Oat groats (AAFCO)														
338	Oat groats (CFA)														
339	Hulled oats (CFA)														
340	-groats, grnd cooked, (4)	4-07-982	91.0	3.66	18.4	6.4	3.3	69.5	.08	–	–	–	–	–	.47
341	OATS, WHITE. *Avena sativa*														
342	-grain, Can 2 CW mn wt 36 lb per bushel														
343	mx 3% foreign material, (4)	4-03-378	86.5	3.25	13.2	5.2	12.0	66.1	–	–	–	–	–	–	–

(1) dry forages and roughages; (2) pasture, range plants, and forages fed green; (3) silages;

Dry Basis

Line Number	Potassium (%)	Sodium (%)	Zinc (mg/kg)	Biotin (mg/kg)	Choline (mg/kg)	Folic acid (mg/kg)	Niacin (mg/kg)	Pantothenic acid (mg/kg)	Provitamin A (Carotene) (mg/kg)	Pyridoxine (mg/kg)	Riboflavin (mg/kg)	Thiamin (mg/kg)	Vitamin B_{12} (µg/kg)	Vitamin E (mg/kg)	Vitamin K (mg/kg)
258															
259	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
260															
261															
262	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
263															
264															
265															
266	.54	.65	–	.09	9692.	.22	75.7	9.6	–	3.59	9.8	2.0	.11	9.8	–
267															
268															
269															
270															
271															
272															
273															
274															
275															
276	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
277															
278															
279	1.36	.12	–	–	2047.	3.19	39.1	19.6	.2	–	3.8	5.6	–	–	–
280															
281															
282															
283															
284															
285	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
286															
287															
288	1.52	.15	–	–	1346.	–	33.1	–	–	–	3.2	10.4	–	–	–
289															
290															
291															
292															
293															
294	.09	.28	–	–	1725.	.24	47.2	9.3	–	.72	1.6	.8	–	–	–
295															
296															
297	.16	.05	54.1	.22	1100.	1.20	45.4	7.1	8.4	4.30	3.4	2.2	.25	–	–
298															
299															
300	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
301	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
302															
303															
304	–	.06	–	–	–	–	–	–	–	–	–	–	–	–	–
305															
306															
307															
308															
309															
310															
311															
312															
313	.48	.04	15.4	–	877.	–	58.4	8.2	–	–	1.8	7.3	–	–	–
314															
315															
316	.63	.04	–	–	473.	–	10.7	3.5	–	–	4.9	–	–	–	–
317															
318															
319	.55	.05	483.5	.24	1319.	.38	30.9	25.4	–	2.42	2.0	7.7	–	26.4	–
320															
321															
322	.42	.07	–	.34	1206.	.45	17.8	14.5	–	1.35	1.8	7.0	–	6.6	–
323															
324	.41	.07	–	.12	1209.	.33	19.8	14.3	–	1.43	1.2	–	–	22.0	–
325															
326	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
327															
328															
329	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
330															
331															
332	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
333															
334	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
335															
336	.37	–	–	–	–	–	8.9	16.2	–	1.21	1.4	7.5	–	–	–
337															
338															
339															
340	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
341															
342															
343	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–

(4) energy feeds; (5) protein supplements; (6) minerals; (7) vitamins; (8) additives.

TABLE 6 Composition of Some Common Dog Food Ingredients, Excluding Amino Acids (*Continued*)

				Dry Basis											
Line Number	SCIENTIFIC NAME National Research Council Name (NRC) American Feed Control Name (AAFCO) Canada Feed Act Name (CFA) Other Names	International Reference Number	Dry Matter (%)	ME (kcal/g)	Protein (%)	Ether Extract (%)	Crude Fiber (%)	Nitrogen-Free Extract (%)	Calcium (%)	Copper (mg/kg)	Iodine (mg/kg)	Iron (%)	Magnesium (%)	Manganese (mg/kg)	Phosphorus (%)
344	-grain, Can 2 feed mn wt 28 lb per														
345	bushel mx 22% foreign material, (4)	4-03-379	86.5	3.24	12.7	5.1	12.0	66.8	–	–	–	–	–	–	–
346	-grain, Can 3 CW mn wt 34 lb per bushel														
347	mx 6% foreign material, (4)	4-03-380	86.5	3.25	12.7	5.3	12.1	66.5	–	–	–	–	–	–	–
348	OYSTERS. *Crassostrea* spp, *Ostrea* spp														
349	-shells, fine grnd, mn 33% calcium, (6)	6-03-481	100.0	–	1.0	–	–	–	38.05	–	–	.290	.30	133.3	.07
350	Oyster shell flour (AAFCO)														
351	PEA. *Pisum* spp														
352	-seed, grnd, (5)	5-03-598	91.0	3.14	24.7	2,1	9.9	59.2	.19	–	–	–	–	–	.65
353	PEANUT. *Arachis hypogaea*														
354	-kernels, mech-extd grnd, mx 7% fiber, (5)	5-03-649	92.0	3.44	49.8	8.2	12.0	27.7	.18	–	–	–	.36	27.7	.62
355	Peanut meal, mechanical extracted (AAFCO)														
356	Peanut meal (CFA)														
357	Peanut oil meal, expeller extracted														
358	-kernels, solv-extd grnd, mx 7% fiber, (5)	5-03-650	92.0	2.92	51.5	1.3	14.1	28.2	.22	–	–	–	.04	31.5	.71
359	Peanut meal, solvent extracted (AAFCO)														
360	Groundnut oil meal, solvent extracted														
361	Peanut oil meal, solvent extracted														
362	PHOSPHATE ROCK														
363	-defluorinated grnd, mx 1 part fluorine														
364	per 100 part phosphorus, (6)	6-01-780	99.8	–	–	–	–	–	32.07	–	–	.922	–	–	18.04
365	Phosphete, defluorinated (AAFCO)														
366	Defluorinated phosphate (CFA)														
367	POTATO. *Solanum tuberosum*														
368	-tubers, dehy grnd, (4)	4-07-850	90.3	3.04	6.5	.6	1.6	78.1	.08	–	–	–	–	3.2	.22
369	Potato meal														
370	POULTRY.														
371	-feathers, hydrolyzed dehy grnd, mn 75%														
372	of protein digestible, (5)	5-03-795	94.0	3.50	93.0	2.6	.6	.0	.21	–	–	–	–	–	.89
373	Hydrolyzed poultry feathers (AAFCO)														
374	POULTRY FAT—see ANIMAL														
375	RICE. *Oryza sativa*														
376	-bran w germ, dry milled, mx 13% fiber														
377	$CaCO_3$ declared above 3% mn, (4)	4-03-928	91.0	3.53	14.8	16.6	12.1	44.5	.07	14.3	–	.021	1.04	459.1	2.00
378	Rice bran (AAFCO)														
379	-grain w hulls, grnd, (4)	4-03-938	89.0	3.10	8.2	2.1	10.1	74.6	.04	–	–	–	.16	20.2	.29
380	Ground rough rice (AAFCO)														
381	Ground paddy rice (AAFCO)														
382	-groats, grnd, (4)	4-03-935	89.0	3.53	9.6	1.3	1.1	87.2	.04	4.8	–	.004	.06	4.8	.20
383	Ground brown rice (AAFCO)														
384	Rice grain without hulls, ground														
385	-groats, polished, (4)	4-03-942	89.0	3.51	8.2	.4	.4	90.4	.03	3.3	–	.002	.02	12.2	.13
386	Rice, white, polished														
387	-polishings, dehy, (4)	4-03-943	90.0	3.85	13.1	14.7	3.3	60.0	.04	–	–	–	.72	–	1.58
388	Rice polishings (AAFCO)														
389	Rice polish (CFA)														
390	RYE. *Secale cereale*														
391	-grain, (4)	4-04-047	89.0	3.47	13.4	1.8	2.2	80.7	.07	8.8	–	.009	.13	75.2	.38
392	SESAME. *Sesamum indicum*														
393	-seed, mech-extd grnd, (5)	5-04-220	93.0	3.26	51.5	5.5	5.4	27.6	2.18	–	–	–	–	51.6	1.39
394	Sesame oil meal, expeller extracted														
395	SEAWEED. Laminariales (order), Fucales														
396	(order)														
397	-entire plant, s-c grnd, (1)	1-04-190	89.4	–	10.7	–	8.6	–	2.05	–	–	–	7.12	–	.20
398	SHRIMP. *Pandalus* spp, *Penaeus* spp														
399	-process residue, dehy grnd, salt declared														
400	above 3% mx 7%, (5)	5-04-226	90.0	2.19	52.7	3.2	12.2	1.7	8.17	–	–	.010	.60	33.4	1.77
401	Shrimp meal (AAFCO)														
402	SODIUM PHOSPHATE, MONOBASIC														
403	-technical, (6)	6-04-288	96.7	–	–	–	–	–	–	–	–	–	–	–	22.46
404	Monosodium phosphate (AAFCO)														
405	SODIUM TRIPOLYPHOSPHATE														
406	-commercial, (6)	6-08-076	96.0	–	–	–	–	–	–	–	–	–	–	–	25.98
407	Sodium tripolyphosphate (AAFCO)														
408	SORGHUM, GRAIN VARIETY. *Sorghum vulgare*														
409	-grain, (4)	4-04-383	89.0	3.55	12.5	3.4	2.2	79.9	.45	10.9	–	–	.19	16.3	.35
410	SORGHUM, MILO. *Sorghum vulgare*														
411	-grain, (4)	4-04-444	89.0	3.54	12.4	3.1	2.2	80.4	.45	15.8	–	–	.22	14.5	.33
412	SOYBEAN. *Glycine max*														
413	-oil, (4)	4-07-983	100.0	8.93	–	100.0	–	–	–	–	–	–	–	–	–
414	-seed, mech-extd grnd, mx 7% fiber, (5)	5-04-600	90.0	3.33	48.7	5.2	6.7	33.1	.30	20.0	–	.018	.28	35.9	.70
415	Soybean meal, mechanical extracted (AAFCO)														
416	Soybean meal, expeller extracted														
417	Soybean meal, hydraulic extracted														
418	Soybean oil meal, expeller extracted														
419	Soybean oil meal, hydraulic extracted														
420	-seed, solv-extd grnd, mx 7% fiber, (5)	5-04-604	89.0	3.11	51.5	1.0	6.7	34.3	.36	40.8	–	.013	.30	30.9	.75
421	Soybean meal, solvent extracted														
422	(AAFCO)														
423	Soybean meal, solvent extracted														
424	Soybean oil meal, solvent extracted														
425	-seed wo hulls, solv-extd grnd, mx 3%														
426	fiber, (5)	5-04-612	89.8	3.24	56.7	.9	3.1	33.1	.29	–	–	–	–	50.7	.69
427	Soybean meal, dehulled, solvent														
428	extracted (AAFCO)														

(1) dry forages and roughages; (2) pasture, range plants, and forages fed green; (3) silages;

	Dry Basis														
Line Number	Potassium (%)	Sodium (%)	Zinc (mg/kg)	Biotin (mg/kg)	Choline (mg/kg)	Folic acid (mg/kg)	Niacin (mg/kg)	Pantothenic acid (mg/kg)	Provitamin A (Carotene) (mg/kg)	Pyridoxine (mg/kg)	Riboflavin (mg/kg)	Thiamin (mg/kg)	Vitamin B_{12} (µg/kg)	Vitamin E (mg/kg)	Vitamin K (mg/kg)
344															
345	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
346															
347	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
348															
349	.10	.21	–	–	–	–	–	–	–	–	–	–	–	–	–
350															
351															
352	1.13	.04	33.0	.20	713.	.40	18.9	5.1	–	1.10	.9	2.0	–	–	–
353															
354	1.25	–	–	–	1829.	–	183.7	52.4	–	–	5.8	7.9	–	–	–
355															
356															
357															
358	1.30	.08	21.7	.42	2174.	.39	184.9	57.6	–	10.87	12.0	7.9	–	3.3	–
359															
360															
361															
362															
363															
364	.09	3.96	–	–	–	–	–	–	–	–	–	–	–	–	–
365															
366															
357															
368	2.18	–	–	–	–	–	–	–	–	–	–	–	–	–	–
369															
370															
371															
372	–	–	–	–	977.	–	34.2	12.2	–	–	2.4	–	–	–	–
373															
374															
375															
376															
377	1.91	.08	32.9	4.62	1378.	–	333.2	25.8	–	–	2.9	24.6	–	65.9	–
378															
379	.38	.07	16.9	–	899.	.45	34.0	.37	–	–	1.2	3.1	–	15.7	–
380															
381															
382	.13	.04	–	–	–	–	19.2	–	–	–	.3	1.2	–	–	–
383															
384															
385	.15	.03	2.0	–	1019.	.17	15.8	3.7	–	.45	.7	.7	–	4.0	–
386															
387	1.30	.12	–	.67	1452.	–	590.8	64.8	–	–	2.0	21.9	–	100.0	–
388															
389															
390															
391	.51	.02	34.3	.07	–	.67	1.3	7.8	–	–	1.8	4.4	–	16.8	–
392															
393	1.29	.04	107.5	–	1648.	–	32.3	6.9	–	13.44	4.0	3.1	–	–	–
394															
395															
396															
397	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
398															
399															
400	–	–	–	–	6476.	–	–	–	–	–	4.4	–	–	–	–
401															
402															
403	–	33.4	–	–	–	–	–	–	–	–	–	–	–	–	–
404															
405															
406	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
407															
408															
409	.38	.04	15.4	2.92	762.	.22	48.4	12.5	–	5.95	1.5	4.6	–	–	–
410															
411	.39	.01	19.1	.20	762.	.27	48.0	12.8	–	4.61	1.3	4.8	–	13.5	–
412															
413	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
414	1.90	.27	–	.33	2970.	7.33	33.8	–	–	–	–	4.4	–	–	–
415															
416															
417															
418															
419															
420	2.21	.38	30.3	.36	3082.	.79	30.1	16.3	–	8.99	3.7	7.4	–	3.4	–
421															
422															
423															
424															
425															
426	2.26	.01	50.1	.36	3076.	4.01	24.1	16.1	–	8.91	3.5	2.7	–	3.7	–
427															
428															

(4) energy feeds; (5) protein supplements; (6) minerals; (7) vitamins; (8) additives.

TABLE 6 Composition of Some Common Dog Food Ingredients, Excluding Amino Acids (*Continued*)

Line Number	SCIENTIFIC NAME National Research Council Name (NRC) American Feed Control Name (AAFCO) Canada Feed Act Name (CFA) Other Names	International Reference Number	Dry Matter (%)	Dry Basis ME (kcal/g)	Protein (%)	Ether Extract (%)	Crude Fiber (%)	Nitrogen-Free Extract (%)	Calcium (%)	Copper (mg/kg)	Iodine (mg/kg)	Iron (%)	Magnesium (%)	Manganese (mg/kg)	Phosphorus (%)
429	Soybean oil meal, dehulled, solvent														
430	extracted														
431	SUGARCANE. *Saccharum officinarum*														
432	-molasses, dehy, (4)	4-04-695	96.0	3.10	10.7	1.0	5.2	74.8	–	–	–	–	–	–	–
433	Cane molasses, dried														
434	Molasses, cane, dried														
435	-molasses, mn 48% invert sugar mn 79.5														
436	degrees brix, (4)	4-04-696	75.0	3.15	4.3	.1	–	84.8	1.19	79.5	–	.025	.47	56.3	.11
437	Cane molasses (AAFCO)														
438	Molasses, cane														
439	SUNFLOWER. *Helianthus* spp														
440	-seed wo hulls, mech-extd grnd, (5)	5-04-738	93.0	3.19	44.1	8.2	14.0	26.4	.46	–	–	–	–	24.6	1.12
441	Sunflower meal (AAFCO)														
442	Sunflower oil meal, without hulls,														
443	expeller extracted														
444	-seed wo hulls, solv-extd grnd, (5)	5-04-739	93.0	2.97	50.3	3.1	11.8	26.5	.43	–	–	–	–	24.7	1.08
445	Sunflower meal (AAFCO)														
446	Sunflower oil meal, without hulls,														
447	solvent extracted														
448	SWINE. *Sus scrofa*														
449	-lard, (4)	4-04-790	100.0	8.93	.0	100.0	–	–	–	–	–	–	–	–	–
450	TANKAGE-see ANIMAL														
451	TOMATO. *Lycopersicon esculentum*														
452	-pulp, dehy, (5)	5-05-041	92.0	–	23.6	14.1	31.5	–	.30	–	–	–	–	–	.62
453	Dried tomato pomace (AAFCO)														
454	TURKEY. *Meleagris gallapavo*														
455	-offal mature birds, raw, (5)	5-07-984	28.0	–	–	43.9	1.4	–	–	–	–	–	–	–	–
456	-offal young birds, raw, (5)	5-07-985	35.0	–	–	42.6	.9	–	–	–	–	–	–	–	–
457	-meat, raw, (5)	5-07-986	26.0	3.58	81.9	8.1	.0	–	–	–	–	–	–	–	–
458	WHEAT. *Triticum* spp														
459	-bran, dry milled, (4)	4-05-190	89.0	3.12	18.0	4.6	11.2	59.3	.16	13.8	–	.019	.62	130.0	1.31
460	Wheat bran (AAFCO)														
461	Bran (CFA)														
462	WHEAT. *Triticum* spp														
463	-flour, coarse bolted, feed gr mx 2%														
464	fiber, (4)	4-05-199	89.0	3.49	17.8	3.3	3.4	73.1	.03	5.2	–	.002	–	50.4	.31
465	Wheat feed flour, mx 1.5% fiber (AAFCO)														
466	Feed flour, mx 2.0% fiber (CFA)														
467	-flour byproduct, coarse sifted, mx 7%														
468	fiber, (4)	4-05-201	90.0	3.42	20.4	4.7	5.6	65.0	.12	10.2	–	.011	.29	116.1	.84
469	Wheat shorts, mx 7% fiber (AAFCO)														
470	Shorts, mx 8% fiber (CFA)														
471	-flour byproduct, fine sifted, mx 4%														
472	fiber, (4)	4-05-203	89.0	3.56	20.2	4.0	2.2	70.8	.09	4.9	–	.007	.33	42.2	.58
473	Wheat red dog, mx 4.0% fiber (AAFCO)														
474	Middlings, mx 4.5% fiber (CFA)														
475	-flour byproduct, mill run, mx 9.5%														
476	fiber, (4)	4-05-206	90.0	3.23	17.0	4.4	8.9	63.9	.10	20.8	–	.010	.57	114.1	1.13
477	Wheat mill run (AAFCO)														
478	-grain, (4)	4-05-211	89.0	3.44	14.3	1.9	3.4	78.6	.06	8.1	–	.006	.18	54.8	.40
479	-grain, Pacific coast, (4)	4-08-142	89.2	3.46	11.1	2.2	3.0	81.6	.14	–	–	–	–	–	.34
480	-grain screenings, (4)	4-05-216	89.0	3.29	16.9	3.4	7.9	68.2	.09	–	–	–	–	32.1	.40
481	-grits, cracked fine screened, (4)	4-07-852	88.0	3.53	12.6	1.2	.3	84.5	–	–	–	–	–	–	–
482	Farina														
483	Wheat endosperm														
484	-germ, grnd, mn 25% protein 7% fat, (5)	5-05-218	90.0	3.86	29.1	12.1	3.3	50.7	.08	9.8	–	.012	–	149.9	1.16
485	Wheat germ meal (AAFCO)														
486	WHEAT, DURUM. *Triticum durum*														
487	-grain, (4)	4-05-224	89.5	3.48	15.0	2.2	2.5	78.3	.17	8.6	–	.004	–	32.1	.45
488	-grain, Can 4 CW mn wt 56 lb per bushel														
489	mx 2.5% foreign material, (4)	4-05-225	86.5	3.47	15.7	1.9	2.6	78.0	–	–	–	–	–	–	–
490	WHEAT, HARD RED SPRING. *Triticum aestivum*														
491	-grain, (4)	4-05-258	86.5	3.45	16.1	2.2	3.5	76.3	.06	12.2	–	.006	–	71.9	.46
492	WHEAT, HARD RED WINTER. *Triticum aestivum*														
493	-grain, (4)	4-05-268	89.1	3.44	14.6	1.8	3.0	78.6	.06	5.0	–	–	.11	36.8	.45
494	WHEAT, RED SPRING. *Triticum aestivum*														
495	-grain, Can 4 No mn wt 56 lb per bushel														
496	mx 2.5% foreign material, (4)	4-05-282	86.5	3.47	16.3	2.0	2.8	77.2	–	–	–	–	–	–	–
497	WHEAT, SOFT. *Triticum aestivum*														
498	-grain, (4)	4-05-284	90.0	3.46	12.0	1.9	2.6	81.5	.10	10.8	–	.006	.11	57.0	.33
499	WHEAT, SOFT RED WINTER. *Triticum aestivum*														
500	-grain, (4)	4-05-294	89.1	3.46	12.3	1.8	2.5	81.4	.10	11.0	–	–	.11	42.9	.33
501	WHEY–see CATTLE														
502	YEAST. *Saccharomyces cerevisiae*														
503	-brewers saccharomyces, dehy grnd, mn														
504	40% protein, (7)	7-05-527	93.0	3.23	48.0	1.2	3.2	40.8	.14	35.5	–	.011	.25	6.1	1.54
505	Brewers dried yeast (AAFCO)														
506	-petroleum saccharomyces, dehy grnd, (7)	7-09-836	92.0	–	51.1	–	–	–	.02	–	–	–	–	.	5.87
507	-primary saccharomyces, dehy, mn 40%														
508	protein, (7)	7-05-533	93.0	3.16	51.6	1.1	3.2	35.5	.39	–	–	.030	.39	4.0	1.85
509	Dried yeast (AAFCO)														
510	Primary dried yeast (AAFCO)														
511	YEAST, TORULOPSIS. *Torulopsis utilis*														
512	-dehy, mn 40% protein, (7)	7-05-534	93.0	3.29	51.9	2.7	2.2	34.8	.61	14.4	–	.010	.14	1.81	2.02
513	Torula dried yeast (AAFCO)														

(1) dry forages and roughages; (2) pasture, range plants, and forages fed green; (3) silages;

Line Number	Dry Basis Potassium (%)	Sodium (%)	Zinc (mg/kg)	Biotin (mg/kg)	Choline (mg/kg)	Folic acid (mg/kg)	Niacin (mg/kg)	Pantothenic acid (mg/kg)	Provitamin A (Carotene) (mg/kg)	Pyridoxine (mg/kg)	Riboflavin (mg/kg)	Thiamin (mg/kg)	Vitamin B_{12} (μg/kg)	Vitamin E (mg/kg)	Vitamin K (mg/kg)
429															
430															
431															
432	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
433															
434															
435															
436	3.17	–	–	–	1168.	–	45.7	51.1	–	–	4.4	1.2	–	–	–
437															
438															
439															
440	1.16	–	–	–	–	–	–	–	–	–	–	–	–	–	–
441															
442															
443															
444	1.08	–	–	–	3118.	–	236.6	10.1	–	17.20	3.3	–	–	11.8	–
445															
446															
447															
448															
449	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
450															
451															
452	–	–	–	–	–	–	–	–	–	–	6.7	12.9	–	–	–
453															
454															
455	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
456	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
457	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
458															
459	1.39	.07	–	.54	1110.	2.02	235.1	32.6	–	11.24	3.5	8.9	–	12.1	–
460															
461															
462															
463															
464	–	–	–	–	–	–	47.1	1.0	–	–	–	6.6	–	–	–
465															
466															
467															
468	.94	.08	–	.41	1031.	1.22	105.1	19.6	–	12.22	2.2	17.6	–	33.2	–
469															
470															
471															
472	.67	.74	–	.42	1247.	1.25	59.1	15.3	–	12.47	1.7	21.2	–	64.7	–
473															
474															
475															
476	1.42	.24	–	–	1090.	–	124.4	14.7	–	–	2.7	16.9	–	–	–
477															
478	.58	.10	15.4	.11	933.	.46	63.6	13.6	–	–	1.3	5.5	–	17.4	–
479	–	–	–	–	–	–	66.3	12.9	–	–	1.2	5.5	–	–	–
480	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
481	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
482															
483															
484	–	.06	–	.24	3344.	2.22	52.6	12.4	–	14.44	5.7	31.0	–	147.4	–
485															
486															
487	–	–	–	–	–	.44	–	–	–	–	–	7.0	–	–	–
488															
489	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
490															
491	.58	.07	16.2	.13	899.	.49	66.8	15.6	–	4.62	1.3	3.7	–	12.7	–
492															
493	.57	.07	15.7	.12	824.	.46	57.1	14.3	–	4.60	1.1	7.0	–	12.3	–
494															
495															
496	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
497															
498	.44	.07	15.6	.12	876.	.33	65.8	14.2	–	5.33	1.3	5.3	–	12.2	–
499															
500	.44	–	–	–	874.	.45	64.4	12.8	–	5.16	–	5.9	–	–	–
501															
502															
503															
504	1.85	.08	41.6	5.91	4177.	10.43	481.2	118.1	–	46.56	37.6	98.6	–	.0	–
505															
506	4.02	–	–	–	–	–	–	–	–	–	–	–	–	–	–
507															
508	–	–	–	1.72	–	33.33	322.7	334.7	–	–	41.6	6.9	–	–	–
509															
510															
511															
512	–	.01	106.7	1.20	3129.	25.00	537.8	89.1	–	31.70	47.7	6.7	–	–	–
513															

(4) energy feeds; (5) protein supplements; (6) minerals; (7) vitamins; (8) additives.

TABLE 7 Amino Acid Composition of Some Common Dog Food Ingredients

Line Number	SCIENTIFIC NAME National Research Council Name (NRC) American Feed Control Name (AAFCO) Canada Feed Act Name (CFA) Other Names	International Reference Number	Dry Matter (%)	Dry Basis: Arginine (%)	Cystine (%)	Histidine (%)	Isoleucine (%)	Leucine (%)	Lysine (%)	Methionine (%)	Phenylalanine (%)	Threonine (%)	Tryptophan (%)	Tyrosine (%)	Valine (%)
1	ALFALFA. *Medicago sativa*														
2	-aerial part, dehy grnd, mn 15% protein, (1)	1-00-022	93.1	.64	.18	.32	.73	1.18	.64	.21	.86	.64	.43	.43	.75
3	-aerial part, dehy grnd, mn 17% protein, (1)	1-00-023	93.0	.75	.34	.43	.75	1.40	.86	.21	.86	.86	.43	.54	.97
4	-aerial part, dehy grnd, mn 20% protein, (1)	1-00-024	93.1	.97	–	.43	.86	1.61	.97	.32	1.18	.97	.54	.75	.11
5	ANIMAL. Scientific name not used														
6	-blood, dehy grnd, (5)	5-00-380	91.0	3.85	1.53	4.62	1.10	11.32	7.58	.99	6.70	4.07	1.21	1.98	7.14
7	Blood meal (AAFCO)														
8	Blood meal (CFA)														
9	-blood, spray dehy, (5)	5-00-381	91.0	3.63	–	5.27	1.21	11.65	9.01	1.10	6.15	3.96	1.10	2.20	7.91
10	Blood flour														
11	-carcass residue, dry rendered dehy														
12	grnd, mx 4.4% phosphorus, (5)	5-00-385	93.5	3.96	.64	1.18	2.03	3.74	4.06	.86	2.03	1.93	.32	.96	2.78
13	Meat meal (AAFCO)														
14	Meat scrap														
15	-carcass residue w blood, dry or wet														
16	rendered dehy grnd, mx 4.4%														
17	phosphorus, (5)	5-00-386	92.0	3.91	–	2.07	2.07	5.54	4.34	.87	2.93	2.61	.76	–	4.57
18	Meat meal tankage														
19	Digester tankage														
20	-carcass residue w bone, dry rendered dehy														
21	grnd, mn 4.4% phosphorus, (5)	5-00-388	94.0	4.26	.64	.96	1.80	3.30	3.72	.74	1.91	1.91	.21	.85	2.55
22	Meat and bone meal (AAFCO)														
23	Meat and bone scrap														
24	-liver, dehy grnd, (5)	5-00-389	92.6	4.43	.97	1.62	3.67	5.83	5.18	1.40	3.13	2.81	.65	1.84	4.54
25	Animal liver meal (AAFCO)														
26	Animal liver meal (CFA)														
27	Liver meal														
28	-bone, steamed dehy grnd, (6)	6-00-400	95.0	–	–	–	–	–	–	–	–	–	–	–	–
29	Bone meal, steamed (AAFCO)														
30	-bone phosphate, precipitated dehy,														
31	mn 17% phosphorus, (6)	6-00-406	99.0	–	–	–	–	–	–	–	–	–	–	–	–
32	Bone phosphate (AAFCO)														
33	ANIMAL–POULTRY.														
34	-fat, heat rendered, mn 90% fatty acids														
35	mx 2.5% unsaponifiable matter														
36	mx 1% insoluble matter, (4)	4-00-409	99.5	–	–	–	–	–	–	–	–	–	–	–	–
37	Animal fat (AAFCO)														
38	BARLEY. *Hordeum vulgare*														
39	-grain, (4)	4-00-530	89.0	.60	.20	.30	.60	.90	.60	.20	.70	.40	.20	.40	.70
40	-grain, Pacific coast, (4)	4-07-939	89.0	.48	.25	.25	.45	.67	.34	.16	.54	–	.15	–	.52
41	-malt sprouts w hulls, dehy, mn 24%														
42	protein, (5)	5-00-545	93.0	–	–	–	–	–	–	–	–	–	–	–	–
43	Malt sprouts (AAFCO)														
44	BEET, SUGAR. *Beta saccharifera*														
45	-molasses, mn 48% invert sugar mn 79.5														
46	degrees brix, (4)	4-00-668	77.0	–	–	–	–	–	–	–	–	–	–	–	–
47	Beet molasses (AAFCO)														
48	Molasses (CFA)														
49	-pulp, dehy, (4)	4-00-669	91.0	.33	–	.22	.33	.66	.66	–	.33	.44	.11	.44	.44
50	Dried beet pulp (AAFCO)														
51	Dried beet pulp (CFA)														
52	BLOOD–see ANIMAL														
53	BONE–see ANIMAL														
54	BREAD.														
55	-dehy, (4)	4-07-944	95.0	–	–	–	–	–	–	–	–	–	–	–	–
56	BREWERS–see GRAINS														
57	BUTTERMILK–see CATTLE														
58	CALCIUM PHOSPHATE, DIBASIC														
59	-commercial, (6)	6-01-080	96.0	–	–	–	–	–	–	–	–	–	–	–	–
60	Dicalcium phosphate (AAFCO)														
61	CALCIUM–also see LIMESTONE														
62	Calcium Carbonate, $CaCO_3$														
63	-commercial mn 38%														
64	calcium, (6)														
65	CASEIN–see CATTLE														
66	CATTLE. *Bos* spp														
67	-whey, dehy, mn 65% lactose, (4)	4-01-182	94.0	.43	.32	.21	.96	1.49	1.17	.21	.43	.85	.21	.32	.74
68	Dried whey (AAFCO)														
69	Whey, dried														
70	-whey low lactose, dehy, mn	4-01-186	91.0	.55	.38	–	–	–	1.43	.24	–	–	.24	–	–
71	lactose, declared, (4)														
72	Dried whey-product (AAFCO)														
73	-buttermilk, condensed, mn 27% total														
74	solids w mn 0.055% fat mx 0.14% ash														
75	per 1% solids, (5)	5-01-159	29.0	–	–	–	–	–	–	–	–	–	–	–	–
76	Condensed buttermilk (AAFCO)														
77	Buttermilk, concentrated														
78	Buttermilk, condensed														
79	Buttermilk, evaporated														
80	-buttermilk, dehy, feed gr mx 8% moisture														
81	mx 13% ash mn 5% fat, (5)	5-01-160	93.0	1.18	.43	.97	2.90	3.66	2.58	.75	1.61	1.72	.54	1.08	3.01
82	Dried buttermilk, feed grade (AAFCO)														
83	Buttermilk, dried														
84	-casein, milk acid precipitated dehy,														
85	mn 80% protein, (5)	5-01-162	90.0	3.78	.33	2.78	6.33	9.56	7.78	3.00	5.11	4.22	1.11	5.22	7.56
86	Casein (AAFCO)														
87	Casein, dried														
88	-lips, raw, (5)	5-07-940	30.0	–	–	–	–	–	–	–	–	–	–	–	–

(1) dry forages and roughages; (2) pasture, range plants, and forages fed green; (3) silages; (4) energy feeds; (5) protein supplements; (6) minerals; (7) vitamins; (8) additives.

TABLE 7 Amino Acid Composition of Some Common Dog Food Ingredients (*Continued*)

Line Number	SCIENTIFIC NAME National Research Council Name (NRC) American Feed Control Name (AAFCO) Canada Feed Act Name (CFA) Other Names	International Reference Number	Dry Matter (%)	Dry Basis Arginine (%)	Cystine (%)	Histidine (%)	Isoleucine (%)	Leucine (%)	Lysine (%)	Methionine (%)	Phenylalanine (%)	Threonine (%)	Tryptophan (%)	Tyrosine (%)	Valine (%)
89	-liver, raw, (5)	5-01-166	26.0	–	–	–	–	–	–	–	–	–	–	–	–
90	Beef liver														
91	-lungs, raw, (5)	5-07-941	20.0	–	–	–	–	–	–	–	–	–	–	–	–
92	-milk, dehy, feed gr mx 8% moisture														
93	mn 26% fat, (5)	5-01-167	93.7	.96	–	.75	1.39	2.67	2.35	.64	1.39	1.07	.43	1.39	1.81
94	Dried whole milk (AAFCO)														
95	Milk, whole, dried														
96	-milk, skimmed dehy, mx 8% moisture, (5)	5-01-175	94.0	1.28	.53	.96	2.45	3.51	2.98	.85	1.60	1.49	.43	1.38	2.34
97	Dried skimmed milk, feed grade (AAFCO)														
98	Milk, skimmed, dried														
99	-spleen, raw, (5)	5-07-942	25.0	–	–	–	–	–	–	–	–	–	–	–	–
100	Cattle, melts, raw														
101	-udders, raw, (5)	5-07-943	25.0	–	–	–	–	–	–	–	–	–	–	–	–
102	CHICKEN. *Gallus domesticus*														
103	-broilers, whole, raw, (5)	5-07-945	68.0	–	–	–	–	–	–	–	–	–	–	–	–
104	-cull hens, whole, raw, (5)	5-07-950	70.0	–	–	–	–	–	–	–	–	–	–	–	–
105	-day-old chicks, whole, raw, (5)	5-07-946	24.4	–	–	–	–	–	–	–	–	–	–	–	–
106	-eggs w shells, raw, (5)	5-01-213	34.1	–	–	–	–	–	–	–	–	–	–	–	–
107	-feet, raw, (5)	5-07-947	47.0	–	–	–	–	–	–	–	–	–	–	–	–
108	-gizzards, raw, (5)	5-07-948	69.0	–	–	–	–	–	–	–	–	–	–	–	–
109	-heads, raw, (5)	5-07-949	33.0	–	–	–	–	–	–	–	–	–	–	–	–
110	-offal w feet, raw, (5)	5-07-951	31.0	–	–	–	–	–	–	–	–	–	–	–	–
111	-offal wo feet, raw, (5)	5-07-952	27.0	–	–	–	–	–	–	–	–	–	–	–	–
112	CITRUS. *Citrus* spp														
113	-pulp wo fines, shredded dehy, (4)	4-01-237	90.0	.22	.12	–	–	–	.22	.09	–	–	.07	–	–
114	Dried citrus pulp (AAFCO)														
115	Citrus pulp, dried														
116	COCONUT. *Cocos nucifera*														
117	-meats, mech-extd grnd, (5)	5-01-572	93.0	–	–	–	–	–	–	–	–	–	–	–	–
118	Coconut meal, mechanical extracted (AAFCO)														
119	Copra meal, expeller (AAFCO)														
120	Coconut meal, hydraulic														
121	Copra meal, hydraulic														
122	-meats, solv-extd grnd, (5)	5-01-573	92.0	2.93	.33	.61	.72	1.62	.70	.32	.98	.71	.22	.61	1.07
123	Coconut meal, solvent extracted (AAFCO)														
124	Solvent extracted copra meal (AAFCO)														
125	CORN. *Zea mays*														
126	-grain, flaked, (4)	4-02-859	97.0	–	–	–	–	–	–	–	–	–	–	–	–
127	Flaked corn (AAFCO)														
128	Corn grain, flaked														
129	-grits byproduct, mn 5% fat, (4)	4-02-887	90.6	.55	.20	.22	.44	.88	.44	.20	.33	.44	.11	.55	.55
130	Hominy feed (AAFCO)														
131	Hominy feed (CFA)														
132	-distillers grains w solubles, dehy,														
133	mn 75% original solids, (5)	5-02-843	91.0	1.10	.44	.66	1.00	2.97	.66	.66	1.32	1.04	.22	.88	1.43
134	Corn distillers dried grains with														
135	solubles (AAFCO)														
136	-distillers solubles, dehy, (5)	5-02-844	95.5	1.20	.42	.66	1.31	2.76	.99	.52	1.36	1.08	.31	.99	1.46
137	Corn distillers dried solubles (AAFCO)														
138	-germ wo solubles, wet milled solv-extd														
139	dehy grnd, (5)	5-02-898	93.0	1.29	.34	–	–	1.83	.97	.38	.86	.97	.32	1.61	1.40
140	Corn germ meal, solvent extracted,														
141	(wet milled) (AAFCO)														
142	-gluten, wet milled dehy, (5)	5-02-900	91.0	1.54	.66	1.10	2.53	8.35	.88	1.10	3.19	1.54	.22	1.10	2.42
143	Corn gluten meal (AAFCO)														
144	Corn gluten meal (CFA)														
145	CORN, DENT YELLOW. *Zea mays indentata*														
146	-grain, (4)	4-02-935	86.0	.58	.10	.23	.47	1.28	.23	.20	.58	.47	.12	–	.47
147	-grain, grnd cooked, (4)	4-07-953	88.0	–	–	–	–	–	–	–	–	–	–	–	–
148	CORN, FLINT. *Zea mays indurata*														
149	-grain, (4)	4-02-948	89.0	–	–	–	–	–	.30	.20	–	–	.10	–	–
150	CORN, WHITE. *Zea mays*														
151	-grits by-prod, mn 5% fat, (4)	4-02-990	89.9	–	–	–	–	–	–	–	–	–	–	–	–
152	White hominy feed (AAFCO)														
153	White hominy feed (CFA)														
154	Hominy, white corn, feed														
155	Corn, white hominy feed														
156	COTTON. *Gossypium* spp														
157	-seed w some hulls, mech-extd grnd, mn 41%														
158	protein mx 14% fiber mn 2% fat, (5)	5-01-617	94.0	4.52	.90	1.17	1.70	2.66	1.81	.69	2.50	1.54	.69	.74	2.18
159	Cottonseed meal, 41% protein														
160	-seed w some hulls, pre-press solv-extd														
161	grnd, 41% protein, (5)	5-07-872	92.5	4.59	.92	1.19	1.73	2.70	1.84	.70	2.54	1.57	.70	–	2.22
162	Cottonseed meal, pre-press solvent														
163	extracted, 41% protein														
164	-seed w some hulls, solv-extd grnd, mn 41%														
165	protein mx 14% fiber mn 0.5% fat, (5)	5-01-621	91.5	4.64	.93	1.20	1.75	2.73	1.86	.71	2.57	1.58	.71	.77	2.24
166	Cottonseed meal, solvent extracted,														
167	41% protein														
168	-seed wo hulls, pre-press solv-extd grnd,														
169	mn 50% protein, (5)	5-07-874	92.5	5.14	1.08	1.35	2.00	3.03	2.27	.86	2.97	1.84	.76	.86	2.22
170	Cottonseed meal, pre-press solvent														
171	extracted, 50% protein														
172	CRAB. *Callinectes sapidus, Cancer* spp														
173	*Paralithodes canschatica*														
174	-processed residue, dehy grnd, mn 25%														
175	protein salt declared above 3%														
176	mx 7%, (5)	5-01-663	93.0	1.83	–	.54	1.29	1.72	1.50	.54	1.29	1.08	.32	1.29	1.61

(1) dry forages and roughages; (2) pasture, range plants, and forages fed green; (3) silages; (4) energy feeds; (5) protein supplements; (6) minerals; (7) vitamins; (8) additives.

TABLE 7 Amino Acid Composition of Some Common Dog Food Ingredients (*Continued*)

Line Number	SCIENTIFIC NAME / National Research Council Name (NRC) / American Feed Control Name (AAFCO) / Canada Feed Act Name (CFA) / Other Names	International Reference Number	Dry Matter (%)	Dry Basis: Arginine (%)	Cystine (%)	Histidine (%)	Isoleucine (%)	Leucine (%)	Lysine (%)	Methionine (%)	Phenylalanine (%)	Threonine (%)	Tryptophan (%)	Tyrosine (%)	Valine (%)
177	Crab meal (AAFCO)														
178	DISTILLERS—see CORN														
179	FAT—see ANIMAL														
180	FISH.														
181	-livers, extn unspecified dehy grnd,														
182	salt declared above 4%, (5)	5-01-968	93.0	–	–	–	–	–	–	–	–	–	–	–	–
183	Fish liver meal (CFA)														
184	-soluble, condensed, mn 30% protein, (5)	5-01-969	51.0	4.71	3.33	4.90	3.14	4.90	5.29	1.96	2.75	2.35	1.57	.98	3.14
185	Condensed fish solubles (AAFCO)														
186	-stickwater soluble, cooked dehy, mn														
187	60% protein, (5)	5-01-971	92.0	2.61	–	2.83	1.85	2.93	3.26	.98	1.41	1.30	.76	.76	2.07
188	Dried fish solubles (AAFCO)														
189	Fish solubles, dried														
190	FISH, ALEWIFE. *Pomolobus pseudoharengus*														
191	-whole, raw, (5)	5-07-964	26.0	4.04	.99	1.34	2.87	5.01	5.30	1.82	2.68	2.88	–	2.13	3.29
192	-whole or cuttings, cooked mech-extd														
193	dehy grnd, (5)	5-09-830	91.0	–	–	–	–	–	–	–	–	–	–	–	–
194	Fish meal, alewife														
195	FISH, ANCHOVY. *Engraulis* spp														
196	-whole or cuttings, cooked mech-extd														
197	dehy grnd, (5)	5-01-985	93.0	4.80	1.08	1.98	3.66	7.54	5.81	2.35	2.67	3.27	.86	1.90	3.81
198	Fish meal, anchovy														
199	FISH, CARP. *Cyprinus carpio*														
200	-whole, raw, (5)	5-01-986	22.0	–	–	–	–	–	–	–	–	–	–	–	–
201	-whole or cuttings, cooked dehy grnd, (5)	5-09-831	90.8	4.64	–	1.46	2.67	4.98	5.75	1.71	2.60	2.97	–	1.99	2.87
202	Fish meal, carp														
203	FISH, CATFISH. *Ictalurus* spp														
204	-whole, raw, (5)	5-07-965	17.5	–	–	–	–	–	–	–	–	–	–	–	–
205	-whole or cuttings, cooked mech-extd dehy														
206	grnd, (5)	5-09-835	93.9	4.45	–	1.21	1.84	3.55	4.03	1.10	1.93	2.32	–	1.35	2.47
207	Fish meal, catfish														
208	-whole or cuttings, cooked mech-extd														
209	press cake, (5)	5-09-834	47.1	8.36	–	2.72	4.03	6.30	7.41	2.12	4.29	5.03	–	3.29	5.05
210	-whole or cuttings, cooked pasteurized, (5)	5-09-833	39.9	4.96	–	1.36	2.43	3.98	4.21	1.30	2.56	2.88	–	1.68	3.13
211	-whole or cuttings, raw, (5)	5-09-832	42.2	3.60	–	1.40	2.65	4.57	4.83	1.14	2.56	2.96	–	1.30	3.36
212	FISH, FLOUNDER. Bothidae (family),														
213	Pleuronectidae (family)														
214	-whole, raw, (5)	5-01-996	17.0	–	–	–	–	–	–	–	–	–	–	–	–
215	FISH, HADDOCK. *Melanogrammus aeglefinus*														
216	-whole, raw, (5)	5-07-966	18.0	–	–	–	–	–	–	–	–	–	–	–	–
217	FISH, HAKE. *Merluccius* spp. *Urophycis* spp														
218	-whole, cooked, (5)	5-07-967	30.0	–	–	–	–	–	–	–	–	–	–	–	–
219	-whole, cooked acidified, (5)	5-07-968	25.0	–	–	–	–	–	–	–	–	–	–	–	–
220	-whole, raw, (5)	5-07-969	19.0	–	–	–	–	–	–	–	–	–	–	–	–
221	FISH, HERRING. *Clupea harengus harengus,*														
222	*Clupea harengus pallasi*														
223	-whole, raw, (5)	5-01-999	26.0	–	–	–	–	–	–	–	–	–	–	–	–
224	-whole or cuttings, cooked mech-extd														
225	dehy grnd, (5)	5-02-000	92.0	4.34	1.74	1.41	3.48	5.54	7.93	2.17	2.83	2.83	.98	2.28	3.48
226	Fish meal, herring														
227	FISH, MACKEREL ATLANTIC *Scomber scombrus*														
228	-whole, raw, (5)	5-07-971	32.0	–	–	–	–	–	–	–	–	–	–	–	–
229	FISH, MACKEREL PACIFIC. *Scomber japonicus*														
230	-whole, raw, (5)	5-07-972	31.0	–	–	–	–	–	–	–	–	–	–	–	–
231	FISH, MENHADEN. *Brevoortia tyrannus*														
232	-whole or cuttings, cooked mech-extd														
233	dehy grnd, (5)	5-02-009	92.0	4.34	1.02	1.74	4.46	5.43	5.76	1.96	2.93	3.15	.65	1.74	3.91
234	Fish meal, menhaden														
235	FISH, REDFISH. *Sciaenops ocellata*														
236	-whole, raw, (5)	5-08-113	19.8	–	–	–	–	–	–	–	–	–	–	–	–
237	Drumfish, whole, raw														
238	Ocean perch, whole, raw														
239	-whole or cuttings, cooked mech- extd dehy grnd, (5)	5-07-973	94.2	–	–	–	–	–	–	–	–	–	–	–	–
240	Fish meal, drum														
241	Fish meal, redfish														
242	FISH, ROCKFISH. *Sebastodes* spp														
243	-whole, raw, (5)	5-07-974	32.0	–	–	–	–	–	–	–	–	–	–	–	–
244	FISH, SALMON. *Oncorhynchus* spp. *Salmo* spp														
245	-whole, raw, (5)	5-02-011	35.0	–	–	–	–	–	–	–	–	–	–	–	–
246	-whole or cuttings, cooked mech-extd														
247	dehy grnd, (5)	5-02-012	93.0	5.59	.75	–	–	–	8.17	1.72	–	–	.54	–	–
248	Fish meal, salmon														
249	FISH, SARDINE. *Clupea* spp, *Sardinops* spp														
250	-whole or cuttings, cooked mech-extd														
251	dehy grnd, (5)	5-02-015	93.0	2.90	.86	1.94	3.55	5.05	6.34	2.15	2.80	2.80	.54	3.23	4.41
252	FISH, SMELT. *Asmerus* spp														
253	-whole, raw, (5)	5-07-975	21.0	–	–	–	–	–	–	–	–	–	–	–	–
254	FISH, SOLE. Soleidae (family)														
255	-whole, raw, (5)	5-07-976	19.0	–	–	–	–	–	–	–	–	–	–	–	–
256	FISH, TUNA. *Thunnus thynnus*														
257	-process residue, (5)	5-07-977	44.0	–	–	–	–	–	–	–	–	–	–	–	–
258	-whole or cuttings, cooked mech-extd														
259	dehy grnd, (5)	5-02-023	87.0	8.03	–	–	–	–	7.11	1.95	–	–	1.03	–	2.53
260	Fish meal, tuna														
261	FISH, TURBOT. *Psetta maxima*														
262	-whole, raw, (5)	5-07-978	27.0	–	–	–	–	–	–	–	–	–	–	–	–
263	FISH, WHITE. Gadidae (family), Lophiidae														
264	(family), Rajidae (family)														

(1) dry forages and roughages; (2) pasture, range plants, and forages fed green; (3) silages; (4) energy feeds; (5) protein supplements; (6) minerals; (7) vitamins; (8) additives.

TABLE 7 Amino Acid Composition of Some Common Dog Food Ingredients (*Continued*)

Line Number	SCIENTIFIC NAME National Research Council Name (NRC) American Feed Control Name (AAFCO) Canada Feed Act Name (CFA) Other Names	International Reference Number	Dry Matter (%)	Dry Basis Arginine (%)	Cystine (%)	Histidine (%)	Isoleucine (%)	Leucine (%)	Lysine (%)	Methionine (%)	Phenylalanine (%)	Threonine (%)	Tryptophan (%)	Tyrosine (%)	Valine (%)
265	-whole or cuttings, cooked mech-extd														
266	dehy grnd, mx 4% oil, (5)	5-02-025	92.0	3.80	.98	1.63	3.37	4.89	5.33	1.85	2.72	2.72	.76	2.17	3.48
267	White fish meal (CFA)														
268	Fish, cod, meal														
269	Fish, cusk, meal														
270	Fish, haddock, meal														
271	Fish, hake, meal														
272	Fish, pollock, meal														
273	Fish, monkfish, meal														
274	Fish, skate, meal														
275	FISH, WHITING. *Gadus merlangus*														
276	-whole, raw, (5)	5-07-979	23.0	–	–	–	–	–	–	–	–	–	–	–	–
277	FLAX. *Linum usitatissimum*														
278	-seed, mech-extd grnd, mx 0.5% acid														
279	insoluble ash, (5)	5-02-045	91.0	–	–	–	–	–	–	.77	–	–	–	–	–
280	Linseed meal, mechanical extracted (AAFCO)														
281	Linseed meal (CFA)														
282	Linseed oil meal, expeller extracted														
283	Linseed oil meal, hydraulic extracted														
284	Linseed meal, old process														
285	-seed screenings, mech-extd grnd, (5)	5-02-054	91.0	–	–	–	–	–	–	–	–	–	–	–	–
286	Flaxseed screenings meal (AAFCO)														
287	-seed, solv-extd grnd, mx 0.5% acid														
288	insoluble ash, (5)	5-02-048	91.0	–	–	–	–	–	–	–	–	–	–	–	–
289	Linseed meal, solvent extracted (AAFCO)														
290	Solvent extracted linseed meal (CFA)														
291	Linseed oil meal, solvent extracted														
292	GRAINS.														
293	-brewers grains, dehy, mx 3% dried														
294	spent hops, (5)	5-02-141	92.0	1.41	–	.54	1.63	2.50	.98	.43	1.41	.98	.43	1.30	1.74
295	Brewers dried grains (AAFCO)														
296	Brewers dried grains (CFA)														
297	-distillers grains, dehy, (5)	5-02-144	92.5	1.19	.22	.65	1.08	3.24	.65	.54	1.30	.97	.22	.86	1.41
298	HOMINY FEED–see CORN														
299	HORSE. *Equus caballus*														
300	-meat, raw, (5)	5-07-980	24.0	–	–	–	–	–	–	–	–	–	–	–	–
301	-meat w bone, raw grnd, (5)	5-07-981	36.0	–	–	–	–	–	–	–	–	–	–	–	–
302	LARD–see SWINE														
303	LIMESTONE.														
304	-grnd, mn 33% calcium, (6)	6-02-632	100.0	–	–	–	–	–	–	–	–	–	–	–	–
305	Limestone, ground (AAFCO)														
306	LINSEED–see FLAX														
307	LIVER–see ANIMAL														
308	MAIZE–see CORN														
309	MALT–see BARLEY														
310	MEAT–see ANIMAL														
311	MILK–see CATTLE														
312	MILLET. *Setaria* spp														
313	-grain, (4)	4-03-098	90.0	–	–	–	–	–	–	–	–	–	–	–	–
314	MOLASSES–see BEET, SUGAR, see SUGARCANE														
315	OATS. *Avena sativa*														
316	-hulls, (1)	1-03-281	93.0	.22	.06	.11	.22	.32	.22	.11	.22	.22	.11	.22	.22
317	Oat hulls (AAFCO)														
318	Oat hulls (CFA)														
319	-cereal byproduct, mx 4% fiber, (4)	4-03-303	91.0	.77	.26	.33	.60	1.10	.11	.22	.71	.53	.22	1.00	.82
320	Feeding oat meal (AAFCO)														
321	Oat middlings (CFA)														
322	-grain, (4)	4-03-309	89.0	.80	.20	.20	.60	1.00	.40	.20	.70	.40	.20	.60	.70
323	-grain, gr 1 US mn wt 34 lb per bushel														
324	mx 2% foreign material, (4)	4-03-313	91.0	–	–	–	–	–	–	–	–	–	–	–	–
325	-grain, gr 2 heavy US mn wt 36 lb per														
326	bushel mx 3% foreign material, (4)	4-03-315	89.5	.89	.25	.22	.59	1.01	.55	.20	.67	.45	.18	.59	.78
327	Oats, grain, heavy														
328	-grain, gr 2 US mn wt 32 lb per bushel														
329	mx 3% foreign material, (4)	4-03-316	89.0	–	–	–	–	–	–	–	–	–	–	–	–
330	OATS. *Avena sativa*														
331	-grain, gr 3 US mn wt 30 lb per bushel														
332	mx 4% foreign material, (4)	4-03-317	91.0	–	–	–	–	–	–	–	–	–	–	–	–
333	-grain, gr 4 US mn wt 27 lb per bushel														
334	mx 5% foreign material, (4)	4-03-318	91.2	–	–	–	–	–	–	–	–	–	–	–	–
335	Oats, grain, light														
336	-groats, (4)	4-03-331	91.0	–	–	–	–	–	–	–	–	–	–	–	–
337	Oat groats (AAFCO)														
338	Oat groats (CFA)														
339	Hulled oats (CFA)														
340	-groats, grnd cooked, (4)	4-07-982	91.0	–	–	–	–	–	–	–	–	–	–	–	–
341	OATS, WHITE. *Avena sativa*														
342	-grain, Can 2 CW mn wt 36 lb per bushel														
343	mx 3% foreign material, (4)	4-03-378	86.5	.58	–	.22	.37	.74	.42	.03	.52	.16	–	.17	.59
344	-grain, Can 2 feed mn wt 28 lb per														
345	bushel mx 22% foreign material, (4)	4-03-379	86.5	.54	–	.17	.25	.68	.31	.12	.46	.32	–	.27	.36
346	-grain, Can 3 CW mn wt 34 lb per bushel														
347	mx 6% foreign material, (4)	4-03-380	86.5	.59	–	.18	.28	.69	.34	.12	.49	.34	–	.27	.42
348	OYSTERS. *Crassostrea* spp, *Ostrea* spp														
349	-shells, fine grnd, mn 33% calcium, (6)	6-03-481	100.0	–	–	–	–	–	–	–	–	–	–	–	–
350	Oyster shell flour (AAFCO)														
351	PEA. *Pisum* spp														
352	-seed, grnd, (5)	5-03-598	91.0	1.54	.19	.79	1.21	1.98	1.76	.34	1.43	1.03	.26	–	1.43

(1) dry forages and roughages; (2) pasture, range plants, and forages fed green; (3) silages; (4) energy feeds; (5) protein supplements; (6) minerals; (7) vitamins; (8) additives.

TABLE 7 Amino Acid Composition of Some Common Dog Food Ingredients (*Continued*)

Line Number	SCIENTIFIC NAME National Research Council Name (NRC) American Feed Control Name (AAFCO) Canada Feed Act Name (CFA) Other Names	International Reference Number	Dry Matter (%)	Dry Basis Arginine (%)	Cystine (%)	Histidine (%)	Isoleucine (%)	Leucine (%)	Lysine (%)	Methionine (%)	Phenylalanine (%)	Threonine (%)	Tryptophan (%)	Tyrosine (%)	Valine (%)
353	PEANUT. *Arachis hypogaea*														
354	-kernels, mech-extd grnd, mx 7% fiber, (5)	5-03-649	92.0	5.10	–	1.09	2.17	3.37	1.41	.65	2.50	1.52	.54	–	2.39
355	Peanut meal, mechanical extracted (AAFCO)														
356	Peanut meal (CFA)														
357	Peanut oil meal, expeller extracted														
358	-kernels, solv-extd grnd, mx 7% fiber, (5)	5-03-650	92.0	6.41	.65	1.30	2.17	4.02	2.50	.43	2.93	1.63	.54	1.96	3.04
359	Peanut meal, solvent extracted (AAFCO)														
360	Groundnut oil meal, solvent extracted														
361	Peanut oil meal, solvent extracted														
362	PHOSPHATE ROCK														
363	-defluorinated grnd, mx 1 part fluorine														
364	per 100 part phosphorus, (6)	6-01-780	99.8	–	–	–	–	–	–	–	–	–	–	–	–
365	Phosphate, defluorinated (AAFCO)														
366	Defluorinated phosphate (CFA)														
367	POTATO. *Solanum tuberosum*														
368	-tubers, dehy grnd, (4)	4-07-850	90.3	–	–	–	–	–	–	–	–	–	–	–	–
369	Potato meal														
370	POULTRY.														
371	-feathers, hydrolyzed dehy grnd, mn 75%														
372	of protein digestible, (5)	5-03-795	94.0	6.28	3.79	–	–	–	2.13	.64	–	–	.53	–	–
373	Hydrolyzed poultry feathers (AAFCO)														
374	POULTRY FAT–see ANIMAL														
375	RICE. *Oryza sativa*														
376	-bran w germ, dry milled, mx 13% fiber														
377	CaCO, declared above 3% mn, (4)	4-03-928	91.0	.55	.11	.22	.44	.66	.55	.32	.44	.44	.11	.75	.66
378	Rice bran (AAFCO)														
379	-grain w hulls, grnd, (4)	4-03-938	89.0	.60	.11	.10	.30	.60	.30	.19	.30	.20	.11	.67	.57
380	Ground rough rice (AAFCO)														
381	Ground paddy rice (AAFCO)														
382	-groats, grnd, (4)	4-03-935	89.0	–	–	–	–	–	–	–	–	–	–	–	–
383	Ground brown rice (AAFCO)														
384	Rice grain without hulls, ground														
385	-groats, polished, (4)	4-03-942	89.0	.40	.10	.20	.51	.80	.30	.30	.60	.40	.10	.70	.60
386	Rice, white, polished														
387	-polishing, dehy, (4)	4-03-943	90.0	.55	.11	.11	.33	.56	.56	.30	.33	.33	.11	.70	.93
388	Rice polishings (AAFCO)														
389	Rice polish (CFA)														
390	RYE. *Secale cereale*														
391	-grain, (4)	4-04-047	89.0	.60	.20	.30	.60	.80	.51	.20	.70	.40	.10	.30	.70
392	SESAME. *Sesamum indicum*														
393	-seed, mech-extd grnd, (5)	5-04-220	93.0	5.16	.65	1.18	2.26	3.66	1.40	1.51	2.37	1.72	.84	2.15	2.58
394	Sesame oil meal, expeller extracted														
395	SEAWEED. Laminariales (order), Fucales														
396	(order)														
397	-entire plant, s-c grnd, (1)	1-04-190	89.4	.32	–	.10	.27	.48	.36	.07	.27	.31	–	.15	.39
398	SHRIMP. *Pandalus* spp, *Penaeus* spp														
399	-process residue, dehy grnd, salt declared														
400	above 3% mx 7%, (5)	5-04-226	90.0	–	–	–	–	–	–	–	–	–	–	–	–
401	Shrimp meal (AAFCO)														
402	SODIUM PHOSPHATE, MONOBASIC														
403	-technical, (6)	6-04-288	96.7	–	–	–	–	–	–	–	–	–	–	–	–
404	Monosodium phosphate (AAFCO)														
405	SODIUM TRIPOLYPHOSPHATE														
406	-commercial, (6)	6-08-076	96.0	–	–	–	–	–	–	–	–	–	–	–	–
407	Sodium tripolyphosphate (AAFCO)														
408	SORGHUM, GRAIN VARIETY. *Sorghum vulgare*														
409	-grain, (4)	4-04-383	89.0	.40	.20	.30	.60	1.60	.30	–	.51	.30	.10	.40	.60
410	SORGHUM, MILO. *Sorghum vulgare*														
411	-grain, (4)	4-04-444	89.0	.40	.20	.30	.60	1.60	.30	.10	.51	.30	.10	.40	.60
412	SOYBEAN. *Glycine max*														
413	-oil, (4)	4-07-983	100.0	–	–	–	–	–	–	–	–	–	–	–	–
414	-seed, mech-extd grnd, mx 7% fiber, (5)	5-04-600	90.0	2.89	.67	1.22	3.11	4.00	3.00	.89	2.33	1.89	.67	1.56	2.44
415	Soybean meal, mechanical extracted (AAFCO)														
416	Soybean meal, expeller extracted														
417	Soybean meal, hydraulic extracted														
418	Soybean oil meal, expeller extracted														
419	Soybean oil meal, hydraulic extracted														
420	-seed, solv-extd grnd, mx 7% fiber, (5)	5-04-604	89.0	3.60	.75	1.24	2.80	3.82	3.26	.67	2.47	1.91	.67	1.57	2.70
421	Soybean meal, solvent extracted														
422	(AAFCO)														
423	Soybean meal, solvent extracted														
424	Soybean oil meal, solvent extracted														
425	-seed wo hulls, solv-extd grnd, mx 3%														
426	fiber, (5)	5-04-612	89.8	4.23	.89	1.34	2.90	4.23	3.56	.81	3.01	2.23	.72	2.23	3.01
427	Soybean meal, dehulled, solvent														
428	extracted (AAFCO)														
429	Soybean oil meal, dehulled, solvent														
430	extracted														
431	SUGARCANE. *Saccharum officinarum*														
432	-molasses, dehy, (4)	4-04-695	96.0	–	–	–	–	–	–	–	–	–	–	–	–
433	Cane molasses, dried														
434	Molasses, cane, dried														
435	-molasses, mn 48% invert sugar mn 79.5														
436	degrees brix, (4)	4-04-696	75.0	–	–	–	–	–	–	–	–	–	–	–	–
437	Cane molasses (AAFCO)														
438	Molasses, cane														
439	SUNFLOWER. *Helianthus* spp														

(1) dry forages and roughages; (2) pasture, range plants, and forages fed green; (3) silages; (4) energy feeds; (5) protein supplements; (6) minerals; (7) vitamins; (8) additives.

TABLE 7 Amino Acid Composition of Some Common Dog Food Ingredients (*Continued*)

Line Number	SCIENTIFIC NAME National Research Council Name (NRC) American Feed Control Name (AAFCO) Canada Feed Act Name (CFA) Other Names	International Reference Number	Dry Matter (%)	Dry Basis											
				Arginine (%)	Cystine (%)	Histidine (%)	Isoleucine (%)	Leucine (%)	Lysine (%)	Methionine (%)	Phenylalanine (%)	Threonine (%)	Tryptophan (%)	Tyrosine (%)	Valine (%)
440	-seed wo hulls, mech-extd grnd, (5)	5-04-738	93.0	4.52	.86	1.18	2.58	3.23	2.15	1.72	2.58	1.72	.65	–	2.58
441	Sunflower meal (AAFCO)														
442	Sunflower oil meal, without hulls,														
443	expeller extracted														
444	-seed wo hulls, solv-extd grnd, (5)	5-04-739	93.0	3.76	.75	1.08	2.26	2.80	1.83	1.61	2.37	1.61	.54	–	2.47
445	Sunflower meal (AAFCO)														
446	Sunflower oil meal, without hulls,														
447	solvent extracted														
448	SWINE. *Sus scrofa*														
449	-lard, (4)	4-04-790	100.0	–	–	–	–	–	–	–	–	–	–	–	–
450	TANKAGE—see ANIMAL														
451	TOMATO. *Lycopersicon esculentum*														
452	-pulp, dehy, (5)	5-05-041	92.0	–	–	–	–	–	–	–	–	–	–	–	–
453	Dried tomato pomace (AAFCO)														
454	TURKEY. *Meleagris gallopavo*														
455	-offal mature birds, raw, (5)	5-07-984	28.0	–	–	–	–	–	–	–	–	–	–	–	–
456	-offal young birds, raw, (5)	5-07-985	35.0	–	–	–	–	–	–	–	–	–	–	–	–
457	-meat, raw, (5)														
458	WHEAT. *Triticum* spp														
459	-bran, dry milled, (4)	4-05-190	89.0	1.12	.34	.34	.67	1.01	.67	.11	.56	.45	.34	.45	.79
460	Wheat bran (AAFCO)														
461	Bran (CFA)														
462	WHEAT. *Triticum* spp														
463	-flour, coarse bolted, feed gr mx 2%														
464	fiber, (4)	4-05-199	89.0	.44	–	.33	.67	1.00	.33	.12	.67	.33	.12	.22	.56
465	Wheat feed flour, mx 1.5% fiber (AAFCO)														
466	Feed flour, mx 2.0% fiber (CFA)														
467	-flour byproduct, coarse sifted, mx 7%														
468	fiber, (4)	4-05-201	90.0	1.07	.22	.36	.79	1.35	.79	.20	.79	.56	.22	.45	.87
469	Wheat shorts, mx 7% fiber (AAFCO)														
470	Shorts, mx 8% fiber (CFA)														
471	-flour byproduct, fine sifted, mx 4%														
472	fiber, (4)	4-05-203	89.0	1.11	.22	.44	.78	1.33	.67	.11	.56	.56	.22	.56	.89
473	Wheat red dog, mx 4.0% fiber (AAFCO)														
474	Middlings, mx 4.5% fiber (CFA)														
475	-flour byproduct, mill run, mx 9.5%														
476	fiber, (4)	4-05-206	90.0	–	–	–	–	–	–	–	–	–	–	–	–
477	Wheat mill run (AAFCO)														
478	-grain, (4)	4-05-211	89.0	.80	.20	.30	.60	1.00	.51	.20	.70	.40	.20	.51	.60
479	-grain, Pacific coast, (4)	4-08-142	89.2	–	–	–	–	–	–	–	–	–	–	–	–
480	-grain screenings, (4)	4-05-216	89.0	–	–	–	–	–	–	–	–	–	–	–	–
481	-grits, cracked fine screened, (4)	4-07-852	88.0	.68	.34	.34	1.25	1.93	.45	.23	.68	.45	.34	–	.68
482	Farina														
483	Wheat endosperm														
484	-germ, grnd, mn 25% protein 7% fat, (5)	5-05-218	90.0	1.78	.56	.56	1.33	1.22	1.78	.33	.89	.89	.33	–	1.22
485	Wheat germ meal (AAFCO)														
486	WHEAT, DURUM. *Triticum durum*														
487	-grain, (4)	4-05-224	89.5	–	–	–	–	–	–	–	–	–	–	–	–
488	-grain, Can 4 CW mn wt 56 lb per bushel														
489	mx 2.5% foreign material, (4)	4-05-225	86.5	–	–	–	–	–	–	–	–	–	–	–	–
490	WHEAT, HARD RED SPRING. *Triticum aestivum*														
491	-grain, (4)	4-05-258	86.5	.63	.20	.20	.80	1.10	.40	.20	.90	.40	.20	.90	.80
492	WHEAT, HARD RED WINTER. *Triticum aestivum*														
493	-grain, (4)	4-05-268	89.1	.79	.28	.34	.79	1.01	.51	.22	.79	.47	.20	.67	.67
494	WHEAT, RED SPRING. *Triticum aestivum*														
495	-grain, Can 4 No mn wt 56 lb per bushel														
496	mx 2.5% foreign material, (4)	4-05-282	86.5	–	–	–	–	–	–	–	–	–	–	–	–
497	WHEAT, SOFT. *Triticum aestivum*														
498	-grain, (4)	4-05-284	90.0	.44	.22	.22	.44	.67	.33	.14	.44	.31	.13	.44	.44
499	WHEAT, SOFT RED WINTER. *Triticum aestivum*														
500	-grain, (4)	4-05-294	89.1	.40	.20	.10	–	–	.90	–	–	–	.30	.40	–
501	WHEY—see CATTLE														
502	YEAST. *Saccharomyces cerevisiae*														
503	-brewers saccharomyces, dehy grnd, mn														
504	40% protein, (7)	7-05-527	93.0	2.37	.54	1.18	2.26	3.44	3.23	.75	1.95	2.26	.54	1.61	2.47
505	Brewers dried yeast (AAFCO)														
506	-petroleum saccharomyces, dehy grnd, (7)	7-09-836	92.0	2.22	.50	.97	2.70	3.92	3.90	.89	2.41	3.26	.45	1.93	2.89
507	-primary saccharomyces, dehy, mn 40%														
508	protein, (7)	7-05-533	93.0	2.80	.54	6.02	3.87	4.00	4.09	1.08	2.69	2.69	.43	–	3.44
509	Dried yeast (AAFCO)														
510	Primary dried yeast (AAFCO)														
511	YEAST, TORULOPSIS. *Torulopsis utilis*														
512	-dehy, mn 40% protein, (7)	7-05-534	93.0	2.79	.65	1.51	3.12	3.76	4.09	.86	3.23	2.80	.54	2.26	3.12
513	Torula dried yeast (AAFCO)														

(1) dry forages and roughages; (2) pasture, range plants, and forages fed green; (3) silages; (4) energy feeds; (5) protein supplements; (6) minerals; (7) vitamins; (8) additives.

TABLE 8 Abbreviations for Terms Used in Tables 6 and 7

AAFCO	Association of American Feed Control Officials	mech	mechanical
Can	Canadian	mech-extd	mechanically extracted, expeller-extracted, hydraulic-extracted, or old process
CE	Canadian Eastern		
CGA	Canada Grain Act	μg	microgram
CFA	Canada Feeds Act	mg	milligram
cp	chemically pure	mm	millimeter
CW	Canadian Western	mn	minimum
dehy	dehydrated	mx	maximum
extd	extracted	NRC	National Research Council
extn	extraction	ppm	parts per million
extn unspec	extraction unspecified	s-c	suncured
g	gram(s)	solv-extd	solvent-extracted
grnd	ground	spp	species
ICU	International Chick Unit	US	United States
IU	International Units	USP	United States Pharmacopeia
kcal	kilocalories	w	with
kg	kilogram(s)	wo	without
lb	pound(s)	wt	weight

TABLE 9 Weight-Unit Conversion Factors

Units Given	Units Wanted	For Conversion Multiply by
lb	g	453.6
lb	kg	0.4536
oz	g	28.35
kg	lb	2.2046
kg	mg	1,000,000.
kg	g	1,000.
g	mg	1,000.
g	μg	1,000,000.
mg	μg	1,000.
mg/g	mg/lb	453.6
mg/kg	mg/lb	0.4536
μg/kg	μg/lb	0.4536
Mcal	kcal	1,000.
kcal/kg	kcal/lb	0.4536
kcal/lb	kcal/kg	2.2046
ppm	μg/g	1.
ppm	mg/kg	1.
ppm	mg/lb	0.4536
mg/kg	%	0.0001
ppm	%	0.0001
mg/g	%	0.1
g/kg	%	0.1

TABLE 10 Weight Equivalents

1 lb = 453.6 g = 0.4536 kg = 16 oz
1 oz = 28.35 g
1 kg = 1,000 g = 2.2046 lb
1 g = 1,000 mg
1 mg = 1,000 μg = 0.001 g
1 μg = 0.001 mg = 0.000001 g
1 μg per g or 1 mg per kg is the same as ppm

TABLE 11 Meal-Type Diets for Dogs (Dry Matter 90%)

Ingredient[a]	Diet 1 (%)	Diet 2 (%)
Animal, carcass residue w bone, dry rendered dehy grnd, mx 9% indigestible material mn 4.4% phosphorus, (5)	8.00	15.00
Fish, whole or cuttings, cooked mech-extd dehy grnd, salt declared above 3% mx 7%, (5)	5.00	3.00
Soybean, seed, solv-extd grnd, mx 7% fiber, (5)	12.00	—
Soybean, flour, solv-extd fine sift, mx 3% fiber, (5)	—	19.00
Wheat, germ, grnd, mn 25% protein mn 7% fat, (5)	8.00	5.00
Cattle, milk, skimmed dehy, mx 8% moisture, (5)	4.00	2.50
Grains, cereal, (4)	51.23	—
Corn, grain, flaked, (4)	—	26.75
Wheat, bran, dry milled, (4)	4.00	—
Wheat, grain, flaked, (4)	—	26.70
Animal, fat, hydrolyzed, feed gr mn 85% fatty acids mx 6% unsaponifiable matter mx 1% insoluble matter, (4)	2.00	—
Animal, bone, steamed dehy grnd, (6)	2.00	—
Yeast, brewers saccharomyces, dehy grnd, (7)	2.00	0.50
Grains, fermentation solubles, dehy, (5)	1.00	—
Salt, iodized	0.50	0.25
Vitamin A and D mix[b]	0.25	0.50
Riboflavin supplement[c]	—	0.80
Ferric oxide, red, Fe_2O_3, commercial, (4)	0.02	—

Sources: Campbell and Phillips (1953). Federal Specification N-F-170 (1966). Siedler and Schweigert (1952).

[a] NRC names. See page 30.

[b] 2,250 IU of A, 400 IU of D per g.

[c] Supplies 500 mg/kg of riboflavin.

REFERENCES

NUTRIENT REQUIREMENTS AND SIGNS OF DEFICIENCY

Energy

Abrams, J. T. 1962. The feeding of dogs. W. Green and Sons, Edinburgh.

Arnold, A., and C. A. Elvehjem. 1939. Nutritional requirements of dogs. J. Am. Vet. Med. Assoc. 95:187.

Brody, S., R. C. Proctor, and U. S. Ashworth. 1934. Growth and development with special reference to domestic animals. XXXIV. Basal metabolism, endogenous nitrogen, creatinine and neutral sulphur excretions as functions of body weight. Univ. Mo. Agric. Exp. Stn. Res. Bull. No. 220. University of Missouri, Columbia.

Cowgill, G. R. 1928. The energy factor in relation to food intake: Experiments on the dog. Am. J. Physiol. 85:45.

Durrer, J. L., and J. P. Hannon. 1962. Seasonal variations in caloric intake of dogs living in an arctic environment. Am. J. Physiol. 202:375.

Harris, L. E. 1966. Biological energy interrelationships and glossary of energy terms. National Academy of Sciences, Washington, D. C.

Kleiber, M. 1961. The fire of life. John Wiley and Sons, New York.

Orr, N. W. M. 1965. The food requirements of antarctic sledge dogs, pp. 101–112. *In* O. Graham-Jones [ed.] Canine and feline nutritional requirements. Pergamon Press, London.

Payne, P. R. 1965. Assessment of the protein values of diets in relation to the requirements of the growing dog, pp. 19–31. *In* O. Graham-Jones [ed.] Canine and feline nutritional requirements. Pergamon Press, London.

Platt, B. S., D. S. Miller, and P. R. Payne. 1961. Protein values of human food, pp. 351–374. *In* J. F. Brock [ed.] Recent advances in human nutrition. Little, Brown and Company, Boston.

Rosenthal, H. L., and J. B. Allison. 1951. Some effects of caloric intake on nitrogen balance in dogs. J. Nutr. 44:423.

Carbohydrate

Beazell, J. M., C. R. Schmidt, and A. C. Ivy. 1937. On the effectiveness of orally administered diastase in achylin pancreatica (dog). J. Nutr. 13:29.

Becker, D. E., D. E. Ullrey, S. E. Terrill, and R. A. Notzold. 1954. Failure of the newborn pig to utilize dietary sucrose. Science 120:345.

Bennett, M. J., and E. Coon. 1966. Mellituria and postprandial blood sugar curves in dogs after the ingestion of various carbohydrates with the diet. J. Nutr. 88:163.

Cajori, F. A. 1935. The lactase activity of the intestinal mucosa of the dog and some characteristics of intestinal lactase. J. Biol. Chem. 109:159.

Heiman, V. 1959. Nutrition and feeding of dogs. Feedstuffs, February 14, pp. 18–22.

Ivy, A. C., C. R. Schmidt, and J. Beazell. 1936. Starch digestion in the dog. North Am. Vet. 17:44.

James, W. T., and C. M. McCay. 1950. A study of food intake, activity, and digestive efficiency in different type dogs. Am. J. Vet. Res. 11:412.

Luick, J. R., H. R. Parker, and A. C. Andersen. 1960. Composition of beagle dog milk. Am. J. Physiol. 119:731.

Luick, J. R., A. L. Black, H. R. Parker, and M. G. Simesen. 1962. Glucose metabolism in the lactating beagle dog. Am. J. Physiol. 202:329.

McCay, C. M. 1949. Nutrition of the dog. Comstock Publishing Company, Ithaca, N. Y.

Naismith, D. J., and M. C. Cursiter. 1972. Is there a specific requirement for carbohydrate in the diet? Nutr. Soc. Proc. 31:94A.

Roseboom, B. B., and J. W. Patton. 1929. Starch digestion in the dog. J. Am. Vet. Med. Assoc. 74:768.

Roseboom, B. B., and J. W. Patton. 1932. The digestion and absorption of raw starch in dogs. Am. J. Physiol. 100:178.

Fat

Axelrod, H. E., M. G. Gullberg, and A. F. Morgan. 1951. Carbohydrate metabolism in riboflavin-deficient dogs. Am. J. Physiol. 165:604.

Budde, E. F. 1952. The determination of fat in baked biscuit type of dog foods. J. Assoc. Off. Agric. Chem. 35:799.

Campbell, J. E., and P. H. Phillips. 1953. Some problems on feeding fat to dogs. Southwest. Vet. 6:173.

Cowgill, G. R. 1928. The energy factor in relation to food intake: Experiments on the dog. Am. J. Physiol. 85:45.

Crampton, E. W. 1964. Nutrient-to-calorie ratios in applied nutrition. J. Nutr. 82:353.

Edwards, H. M., Jr. 1964. Fatty acid composition of feeding stuffs. Ga. Agric. Exp. Stn. Tech. Bull. N.S. 36. University of Georgia, Athens.

Elvehjem, C. A., and W. A. Krehl. 1947. Imbalances and dietary interrelationships in nutrition. J. Am. Vet. Med. Assoc. 135:279.

Fiser, R. H., J. B. Rollins, and W. R. Beisel. 1972. Decreased resistance against infectious canine hepatitis in dogs fed a high-fat ration. Am. J. Vet. Res. 33:713.

Hansen, A. E., and H. F. Wiese. 1943. Studies with dogs maintained on diets low in fat. Proc. Soc. Exp. Biol. Med. 52:205.

Hansen, A. E., and H. F. Wiese. 1951. 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. Tex. Rep. Biol. Med. 9:491.

Hansen, A. E., O. Beck, and H. F. Wiese. 1948. Susceptibility to infection manifested by dogs on a low fat diet. Fed. Proc. 7:289.

Hansen, A. E., J. G. Sinclair, and H. F. Wiese. 1954. Sequence of histologic changes in skin of dogs in relation to dietary fat. J. Nutr. 52:541.

Harris, P. L., and N. D. Embree. 1963. Quantitative consideration of the effect of polyunsaturated fatty acid content of the diet upon the requirements for vitamin E. Am. J. Clin. Nutr. 13:385.

Hayes, K. C., S. W. Nielsen, and J. E. Rousseau, Jr. 1969. Vitamin E deficiency and fat stress in the dog. J. Nutr. 99: 196.

Hoffman, H. H. 1953. Report on crude fat in baked dog food. J. Assoc. Off. Agric. Chem. 36:208.

Ivy, A. C. 1936. Starch digestion in the dog. Vet. Med. 31:145.

James, W. T., and C. M. McCay. 1950. A study of food intake, activity, and digestive efficiency in different type dogs. Am. J. Vet. Res. 11:412.

Kraybill, H. R., and P. B. Curtis. 1938. Commercial feeding stuffs. Purdue Univ. Agric. Exp. Stn. Circ. No. 236.

Lindall, A. W., F. Grande, and A. Schultz. 1972. Effect of dietary fats on the serum lipoproteins in thyroidectomized dogs. J. Nutr. 102:515.

Lindall, A. W., F. Grande, and A. Schultz. 1971. The effect of dietary fats on the serum lipoproteins of normal dogs. Proc. Soc. Exp. Biol. Med. 136:1032.

Linton, R. G. 1934. Canine nutrition. 12th Int. Vet. Congr., N. Y. 3:488.

Morgan, A. F. 1935. The food needs of dogs. Vet. J. 91:204.

Morgan, A. F. 1940. Deficiencies and fallacies in canine diet. North Am. Vet. 21:476.

Neumer, J. F., and L. R. Dugan, Jr. 1953. The use of antioxidants in dry dog food. Food Technol. 7:189.

Newberne, P. M. 1966. Overnutrition on resistance of dogs to distemper virus. Fed. Proc. 25:1701.

Nolen, G. A. 1973. A feeding study of a used, partially hydrogenated soybean oil, frying fat in dogs. J. Nutr. 103:1248.

Ontko, J. A., and P. H. Phillips. 1958. Reproduction and lactation studies with bitches fed semipurified diets. J. Nutr. 65: 211.

Ontko, J. A., R. E. Wuthier, and P. H. Phillips. 1957. The effect of increased dietary fat upon the protein requirement of the growing dog. J. Nutr. 62:163.

Orr, N. W. M. 1965. The food requirements of antarctic sledge dogs, pp. 101–112. *In* O. Graham-Jones [ed.] Canine and feline nutritional requirements. Pergamon Press, London.

Prigge, W. F., and F. Grande. 1973. Effects of dietary fat and of a lipolytic agent on postprandial free fatty acids and fasting serum lipids in the dog. J. Nutr. 103:1200.

Siedler, A. J., and B. S. Schweigert. 1952. Effect of the level of fat in the diet on the growth performance of dogs. J. Nutr. 48:81.

Siedler, A. J., and B. S. Schweigert. 1954. Effect of the level of animal fat in the diet on the maintenance, reproduction and lactation performance of dogs. J. Nutr. 53:187.

Steinberg, G., W. H. Slaton, Jr., D. R. Howton, and J. F. Mead. 1956. Metabolism of essential fatty acids. IV. Incorporation of linoleate into arachidonic acid. J. Biol. Chem. 220:257.

Wiese, H. F., A. E. Hansen, and E. Coon. 1962. Influence of high and low caloric intakes on fat-deficiency of dogs. J. Nutr. 76:73.

Wiese, H. F., M. J. Bennett, E. Coon, and W. Yamanaka. 1965. Lipid metabolism of puppies as affected by kind and amount of fat and of dietary carbohydrate. J. Nutr. 86:271.

Wiese, H. F., W. Yamanaka, E. Coon, and S. Barber. 1966. Skin lipids of puppies as affected by kind and amount of dietary fat. J. Nutr. 89:113.

Wikoff, H. L., B. H. Marks, J. F. Caul, and W. F. Hoffman. 1947. Some effects of high lipid diets on intestinal elimination. IV. Saturated fatty acids. Am. J. Dig. Dis. 14:58.

PROTEIN

Abrams, J. T. 1962. The feeding of dogs. W. Green and Sons, Edinburgh.

Afonsky, D. 1954. Folic acid deficiency in the dog. Science 120:803.

Allison, J. B. 1957. Nitrogen balance and the nutritive value of proteins. J. Am. Med. Assoc. 164:283.

Allison, J. B. 1958a. Amino acid requirements. Feedstuffs 30(50):28.

Allison, J. B. 1958b. Balance and imbalance of amino acids both in regard to human and animal nutrition. Voeding 19: 119.

Allison, J. B., J. A. Anderson, and R. D. Seeley. 1945. The determination of the nitrogen balance index in normal and hypoproteinemic dogs. Ann. N.Y. Acad. Sci. 47:245.

Allison, J. B., R. D. Seeley, J. H. Brown, and J. A. Anderson. 1946. The evaluation of proteins in hypoproteinemic dogs. J. Nutr. 31:237.

Allison, J. B., J. A. Anderson, and R. D. Seeley. 1947. Some effects of methionine on the utilization of nitrogen in the adult dog. J. Nutr. 33:361.

Allison, J. B., R. W. Wannemacher, Jr., and J. Migliarese. 1954. Diet and the metabolism of 2-aminofluorene. J. Nutr. 52:415.

Allison, J. B., and R. W. Wannemacher, Jr. 1957. Repletion of depleted protein reserves. *In* W. H. Cole [ed.] Animals in amino acid malnutrition. Rutgers University Press, New Brunswick, N.J.

Allison, J. B., and R. W. Wannemacher, Jr. 1965. The concept and significance of labile and over-all protein reserves of the body. Am. J. Clin. Nutr. 16:445.

Altman, P. L., and D. S. Dittmer. 1968. Metabolism. Biological Handbooks, Federation of American Societies for Experimental Biology, p. 115.

Arnold, A., and C. A. Elvehjem. 1939. Nutritional requirements of dogs. J. Am. Vet. Med. Assoc. 95:187.

Arnold, A., and J. S. Schad. 1954. Nitrogen balance studies with dogs on casein or methionine-supplemented casein. J. Nutr. 53:265.

Block, R. J., and K. W. Weiss. 1956. Amino acid handbook. Charles C. Thomas, Springfield, Ill.

Campbell, J. E. and P. H. Phillips. 1953. Some problems on feeding fat to dogs. Southwest. Vet. 6:173.

Cathcart, E. P. 1921. The physiology of protein metabolism. Longmans Green and Company, London.

Gessert, C. F., and P. H. Phillips. 1956. Protein in the nutrition of the growing dog. J. Nutr. 58:415.

Goddard, K. M., G. D. Williams, P. M. Newberne, and R. B. Wilson. 1970. A comparison of all-meat, semimoist, and dry-type dog foods as diets for growing beagles. J. Am. Vet. Med. Assoc. 157:1233.

Heard, C. R. C., M. R. Turner, and B. S. Platt. 1964. Diabetic-like changes in carbohydrate metabolism in dogs fed diets of suboptimal protein value. Proc. Nutr. Soc. 23(1): vi.

Hegsted, D. M., V. Kent, A. G. Tsongas, and F. J. Stare. 1947. A comparison of the nutritive value of the proteins in mixed diets for dogs, rats, and human beings. J. Lab. Clin. Med. 32:403.

Heiman, V. 1947. The protein requirements of growing puppies. J. Am. Vet. Med. Assoc. 111:304.

James, W. T., and C. M. McCay. 1950. A study of feed intake, activity, and digestive efficiency in different type dogs. Am. J. Vet. Res. 11:412.

Jubb, K. V., and P. C. Kennedy. 1970. Pathology of domestic animals, 2d ed., vol. 2. Academic Press, New York. pp. 287–319.

Kade, C. F., Jr., J. H. Phillips, and W. A. Phillips. 1948. The determination of the minimum requirement of the adult dog for maintenance of nitrogen balance. J. Nutr. 36:109.

Kennedy, G. C. 1957. Effect of old age and over-nutrition on the kidney. Br. Med. Bull. 13:67.

Koehn, C. J. 1942. Practical dog feeding. Ala. Agric. Exp. Stn. Bull. No. 251.

Krook, L. 1971. Metabolic bone diseases of dogs and cats. Proceedings, American Animal Hospital Association, 38: 350.

McCay, C. M. 1949. Nutrition of the dog. Comstock Publishing Company, Ithaca, N. Y.

McCoy, J. R., J. B. Allison, M. L. Crossley, and R. W. Wannemacher, Jr. 1956. Chemotherapy of canine cancer with *N*-(3-oxapentamethylene)-*N'*, *N"*-diethylenephosphoramide (MEPA). Am. J. Vet. Res. 17:90.

McKibbin, J. M., S. Black, and C. A. Elvehjem. 1940. The essential nature of pantothenic acid and another alkali-labile factor in the nutrition of the dog. Am. J. Physiol. 130:365.

Melnick, D., and G. R. Cowgill. 1937. The protein minima for nitrogen equilibrium with different proteins. J. Nutr. 13:401.

Miller, D. S., and P. R. Payne. 1963. A theory of protein metabolism. J. Theor. Biol. 5:398.

Mitchell, H. H. 1950. Some species and age difference in amino acid requirements of mammals. *In* A. A. Albanese [ed.] Protein and amino acid requirements of mammals. Academic Press, New York.

Mitchell, H. H. 1963. Comparative nutrition of man and animals, vol. 1. Academic Press, New York.

Newberne, P. M., and R. B. Wilson. 1971. Nutritional adequacy: The case for the dog. Pet Food Industry, May–June, p. 11.

Ontko, J. A., and P. H. Phillips. 1958. Reproduction and lactation studies with bitches fed semipurified diets. J. Nutr. 65: 211.

Ontko, J. A., R. E. Wuthier, and P. H. Phillips. 1957. The effect of increased dietary fat upon the protein requirement of the growing dog. J. Nutr. 62:163.

Payne, P. R. 1965. Assessment of the protein values of diets in relation to the requirements of the growing dog, pp. 19–31. *In* O. Graham-Jones [ed.] Canine and feline nutritional requirements. Pergamon Press, London.

Rose, W. C., and E. E. Rice. 1939. The significance of the amino acids in canine nutrition. Science 90:186.

Terroine, E. F., and H. Sorg-Matter. 1927. Loi quantitative de la dépense azotée minima des homéothermes; validité interspécifique. Arch. Int. Physiol. 29:121.

Voit, C. 1881. L. Hermann's Handbuch der Physiologie des Gesammtstoffwechsels und der Fortpflanzung. I. Physiologie des allgemeinen Stoffwechsels und der Ernährung. Leipzig.

Wannemacher, R. W., Jr., and J. R. McCoy. 1966. Determination of optimal dietary protein requirements of young and old dogs. J. Nutr. 88:66.

MINERALS

Calcium and Phosphorus

Arnold, A., and C. A. Elvehjem. 1939. Nutritional requirements of dogs. J. Am. Vet. Med. Assoc. 94:187.

Campbell, J. R. 1962. Bone dystrophy in puppies. Vet. Rec. 74: 1340.

Gershoff, S. N., M. A. Legg, and D. M. Hegsted. 1958. Adaptation to different calcium intakes in dogs. J. Nutr. 64: 303.

Hedhammer, A., F. Wu, L. Krook, H. F. Schryver, A. deLahunta, J. P. Whalen, F. A. Kallfelz, E. A. Nunez, H. F. Hintz, B. E. Sheffy, and G. D. Ryan. 1974. Overnutrition and skeletal disease. An experimental study in growing Great Dane dogs. Cornell Vet. 64, Suppl. 5.

Henrikson, P. 1968. Periodontal disease and calcium deficiency. Acta Odontol. Scand., Suppl. 50.

Hoff-Jørgensen, E. 1946. The influence of phytic acid on the absorption of calcium and phosphorus. Biochem. J. 40:189.

Jenkins, K. J., and P. H. Phillips. 1960a. The mineral requirements of the dog. I. Phosphorus requirement and availiblity. J. Nutr. 70:235.

Jenkins, K. J., and P. H. Phillips. 1960b. The mineral requirements of the dog. II. The relation of calcium, phosphorus and fat levels to minimal calcium and phosphorus requirements. J. Nutr. 70:241.

Koehn, C. J. 1942. Practical dog feeding. Ala. Agric. Exp. Stn. Bull. No. 251.

Krook, L., L. Lutwak, P. Henrikson, F. Kallfelz, C. Hirsch, B. Romanus, L. F. Bélanger, J. R. Marier, and B. E. Sheffy. 1971. Reversibility of nutritional osteoporosis: Physicochemical data on bones from an experimental study in dogs. J. Nutr. 101:233.

McCay, C. M. 1949. Nutrition of the dog. Comstock Publishing Company, Ithaca, N. Y.

Mellanby, E. 1920. Accessory food factors (vitamins) in the feeding of infants. Lancet 1:856.

Morgan, A. F. 1934. The effect of acid, neutral, and basic diets on the calcium and phosphorus metabolism of dogs. Univ. Calif. Publ. Physiol. 8:61.

Phillips, P. H., and E. B. Hart. 1935. The effect of organic dietary constituents upon chronic fluorine toxicosis in the rat. J. Biol. Chem. 109:657.

Schedle, H. P., G. W. Osbaldiston, and I. H. Mills. 1968. Absorption, secretion, and precipitation of calcium in the small intestine of the dog. Am. J. Physiol. 214:814.

Udall, R. H., and C. M. McCay. 1953. The feed value of fresh bone. J. Nutr. 49:197.

Iron and Copper

Arriaga de la Cabada, L., J. Labardini, and L. Sánchez-Medal. 1969. Hemolysis and erythropoiesis. V. The utilization of hemoglobin iron by bled anemic dogs. Proc. Soc. Exp. Biol. Med. 131:279.

Bannerman, R. M. 1965. Quantitative aspects of hemoglobin iron absorption. J. Lab. Clin. Med. 65:944.

Bradford, F. K., and P. C. Johnson, Jr. 1962. The passage of iron-labeled erythrocytes from subarachnoid space, aqueous chamber, and other body cavities of dogs into the systemic circulation. Surg. Gyn. Obstet. 115:392.

Bronson, W. R., and T. R. C. Sisson. 1960. Studies on acute iron poisoning. J. Dis. Child. 99:18.

Brown, E. B. 1963. The absorption of iron. Am. J. Clin. Nutr. 12:205.

Brown, E. B., D. E. Smith, R. Dubach, and C. V. Moore. 1959. Lethal iron overload in dogs. J. Lab. Clin. Med. 53: 591.

Cibis, P. A., E. B. Brown, and S. M. Hong. 1957. Ocular effects of systematic siderosis. Am. J. Ophthalmol. 44(2):158.

Cline, M. J., and N. I. Berlin. 1963. Erythropoiesis and red cell survival in hypothyroid dogs. Am. J. Physiol. 204:415.

D'Arcy, P. F., and E. M. Howard. 1962a. Acute toxicity of ferrous salts administered to dogs by mouth. J. Pathol. Bacteriol. 83:65.

D'Arcy, P. F., and E. M. Howard. 1962b. Iron therapy. Pharm. J. 189:223.

Elvehjem, C. A., E. B. Hart, and W. C. Sherman. 1933. The availability of iron from different sources for hemoglobin formation. J. Biol. Chem. 103:61.

Elvehjem, C. A., E. B. Hart, and W. C. Sherman. 1934. Limitations of cereal-milk diets for hemoglobin formation. J. Pediatr. 4:65.

Fitch, C. D., W. E. Harville, J. S. Dinning, and F. S. Porter. 1964. Iron deficiency in monkeys fed diets containing soybean protein. Proc. Soc. Exp. Biol. Med. 116:130.

Foster, A. O., and W. W. Cort. 1932. The relation of diet to the susceptibility of dogs to *Ancylostoma caninum*. Am. J. Hyg. 16:241.

Fritz, J. C., G. W. Pla, T. Roberts, J. W. Boehme, and E. L. Hove. 1970. Biological availability in animals of iron from common dietary sources. J. Agric. Food Chem. 18:647.

Frost, D. V., C. A. Elvehjem, and E. B. Hart. 1939. The role of iron, copper, and cobalt in hemoglobin production in dogs on a milk diet. J. Biol. Chem. 128:xxxi.

Frost, D. V., C. A. Elvehjem, and E. B. Hart. 1940. Iron utilization in dogs on milk diets. J. Nutr. 19:311.

Goldstone, J. M., I. Kushner, and J. W. Harris. 1962. Studies on regulation of plasma iron in dogs with turpentine abscesses. Proc. Soc. Exp. Biol. Med. 110:285.

Hahn, P. F., W. F. Bale, and G. H. Whipple. 1946. Effects of inflammation (turpentine abscess) on iron absorption. Proc. Soc. Exp. Biol. Med. 61:405.

Koepke, J. A., and W. B. Stewart. 1964a. The role of gastric secretion in iron absorption. Fed. Proc. 23:511.

Koepke, J. A., and W. B. Stewart. 1964b. Role of gastric secretion in iron absorption. Proc. Soc. Exp. Biol. Med. 115:927.

Krook, L. 1969. Metabolic bone diseases of endocrine origin, pp. 524–584. *In* Ernst Joests Handbuch der speziellen pathologischen Anatomie der Haustiere, vol. I. Paul Parey, Berlin and Hamburg.

Krook, L., L. Lutwak, P. Henrikson, F. Kallfelz, C. Hirsch, B. Romanus, L. F. Bélanger, J. R. Marier, and B. E. Sheffy. 1971. Reversibility of nutritional osteoporosis: Physicochemical data on bones from an experimental study in dogs. J. Nutr. 101:233.

Linton, R. G. 1934. Canine nutrition. 12th Int. Vet. Congr., N. Y. 3:488.

McCance, R. A., and E. M. Widdowson. 1944. Mineral metabolism. Ann. Rev. Biochem. 8:315.

McCay, C. M. 1949. Nutrition of the dog. Comstock Publishing Company, Ithaca, N. Y.

Moore, C. F. 1963. Hypochromic anaemias not caused by iron deficiency. Australasian Ann. Med. 12:16.

Murray, J. F., P. Gold, and B. L. Johnson, Jr. 1962. Systemic oxygen transport in induced normovolemic anemia and polycythemia. Am. J. Physiol. 203:720.

Phillips, P. H., and E. B. Hart. 1935. The effect of organic dietary constituents upon chronic fluorine toxicosis in the rat. J. Biol. Chem. 109:657.

Pollack, S., S. P. Balcerzak, and W. H. Crosby. 1963. Transferrin and absorption of iron. Blood 21:33.

Pollack, S., R. M. Kaufman, and W. H. Crosby. 1964. An investigation of exchange of iron across the intestinal mucosa. J. Lab. Clin. Med. 63:847.

Potter, V. R., C. A. Elvehjem, and E. B. Hart. 1938. Anemia studies with dogs. J. Biol. Chem. 126:155.

Ruegamer, W. R., L. Michaud, E. B. Hart, and C. A. Elvehjem. 1946. The use of the dog for studies on iron availability. J. Nutr. 32:101.

Sherman, W. C., C. A. Elvehjem, and E. B. Hart. 1934. Further studies on the availability of iron in biological materials. J. Biol. Chem. 107:383.

Stewart, W. B., and S. R. Gambino. 1961. Kinetics of iron absorption in normal dogs. Am. J. Physiol. 201:67.

Talwar, J. R., S. Kumar, and E. J. Lazaro. 1961. The role of duodenum in iron absorption. Indian J. Med. Res. 49:656.

Udall, R. H., and C. M. McCay. 1953. The feed value of fresh bone. J. Nutr. 49:197.

Wintrobe, M. M. 1967. Clinical hematology, 6th ed. Lea & Febiger, Philadelphia. pp. 491–492.

Cobalt

Frost, D. V., C. A. Elvehjem, and E. B. Hart. 1939. The role of iron, copper and cobalt in hemoglobin production in dogs on a milk diet. J. Biol. Chem. 128:xxxi.

Frost, D. V., C. A. Elvehjem, and E. B. Hart. 1940. Iron utilization in dogs on milk diets. J. Nutr. 19:311.

Stanley, A. J., H. C. Hopps, and A. A. Hellbaum. 1946. Observations on cobalt polycythemia. I. Studies on the peripheral blood of rats. Proc. Soc. Exp. Biol. Med. 61:130.

Potassium

Abbrecht, P. H. 1972. Cardiovascular effects of chronic potassium deficiency in the dog. Am. J. Physiol. 223:555.

Burnell, J. M., and J. K. Dawsborn. 1970. Acid-base parameters in potassium depletion in the dog. Am. J. Physiol. 218: 1583.

Phillips, P. H., and E. B. Hart. 1935. The effect of organic dietary constituents upon chronic fluorine toxicosis in the rat. J. Biol. Chem. 109:657.

Ruegamer, W. R., C. A. Elvehjem, and E. B. Hart. 1946. Potassium deficiency in the dog. Proc. Soc. Exp. Biol. Med. 61:234.

Serrano, C. V., L. M. Talbert, and L. G. Welt. 1964. Potassium deficiency in the pregnant dog. J. Clin. Invest. 43:27.

Sodium Chloride

Brubacher, E. S., and A. J. Vander. 1968. Sodium deprivation and renin secretion in unanesthetized dogs. Am. J. Physiol. 214:15.

Bunag, R. D., I. H. Page, and J. W. McCubbin. 1966. Influence of dietary sodium on stimuli causing renin release. Am. J. Physiol. 211:1383.

Ganong, W. F., and A. T. Boreyzka. 1967. Effect of a low-sodium diet on aldosterone-stimulating activity of angiotensin II in dogs. Proc. Soc. Exp. Biol. Med. 124:1230.

McCance, R. A. 1936. Medical problems in mineral metabolism. III. Experimental human salt deficiency. Lancet 230:823.

McCance, R. A., and E. M. Widdowson. 1944. Mineral metabolism. Ann. Rev. Biochem. 13:315.

McCay, C. M. 1949. Nutrition of the dog. Comstock Publishing Company, Ithaca, N. Y.

Iodine

Dammrich, K. 1963. Berl. Münch. Tierärztliche Wochenschr. 73:53. 1963: MVP Reference and Data Library, F-3-71.

Fritz, T. E., W. P. Norris, and N. D. Fretz. 1970. Influence of lymphocytic thyroiditis on iodine metabolism in the beagle. Proc. Soc. Exp. Biol. Med. 134:450.

Marine, D., and C. H. Lenhart. 1909. Effect of the administration or the withholding of iodine-containing compounds in normal colloid or actively hyperplastic (parenchymatous) thyroids of dogs. Arch. Intern. Med. 4:253.

Norris, W. P., T. E. Fritz, and J. A. Taylor. 1970. Cycle of accommodation to restricted dietary iodide in the thyroid gland of the beagle dog. Am. J. Vet. Res. 31:21.

Phillips, P. H., and E. B. Hart. 1935. The effect of organic dietary constituents upon chronic fluorine toxicosis in the rat. J. Biol. Chem. 109:657.

Zinc

Baxter, D. J., R. D. Lindeman, L. R. Miller, and L. J. Greenfield. 1970. Radiozinc uptake into subcellular fractions in acute myocardial infarction. Proc. Cent. Soc. Clin. Res. (Chicago), Nov. 6–7. 1970. J. Lab. Clin. Med. 76:1032.

Montgomery, M. L., G. E. Sheline, and I. L. Chaikoff. 1943. Elimination of administered zinc in pancreatic juice, duodenal juice, and bile of dog as measured by its radioactive isotope (Zn^{65}). J. Exp. Med. 78:151.

Robertson, B. T., and M. J. Burns. 1963. Zinc metabolism and zinc-deficiency syndrome in the dog. Am. J. Vet. Res. 24: 997.

Magnesium

Bunce, G. E., K. J. Jenkins, and P. H. Phillips. 1962a. The mineral requirements of the dog. III. The magnesium requirement. J. Nutr. 76:17.

Bunce, G. E., Y. Chiemchaisri, and P. H. Phillips. 1962b. The mineral requirements of the dog. IV. Effect of certain dietary and physiological factors upon the magnesium deficiency syndrome. J. Nutr. 76:23.

Kahil, M. E., J. E. Parrish, E. L. Simons, and H. Brown. 1966. Magnesium deficiency and carbohydrate metabolism. Diabetes 15:734.

Morris, Jr., M. L. 1963. Magnesium metabolism in the weanling dog. Ph.D. Thesis. University of Wisconsin, Madison. 45 pp.

Vitale, J. J.. E. E. Hellerstein, M. Nakamura, and B. Lown. 1961. Effects of magnesium deficient diet upon puppies. Circ. Res. 9:387.

Manganese

Phillips, P. H., and E. B. Hart. 1935. The effect of organic dietary constituents upon chronic fluorine toxicosis in the rat. J. Biol. Chem. 109:657.

Selenium

Van Vleet, J. 1972. Personal communication. Purdue University, Lafayette, Indiana.

Fluorine

Andreeva, V. S. 1959. Changes in calcium and organic and inorganic phosphorus in blood serum of puppies given sodium fluoride. Fiziol. Z. SSSR Secenova 43:1183. Nutr. Abstr. Rev. 29:1.

Biester, H. E., D. A. Greenwood, and V. E. Nelson. 1936. Pathologic and physiologic studies on dogs receiving fluorine in doses comparable to those encountered in some water supplies. North Am. Vet. 17:38(1937). Nutr. Abstr. Rev. 7:2.

Bunce, G. E., Y. Chiemchaisri, and P. H. Phillips. 1962. The mineral requirements of the dog. IV. Effect of certain dietary and physiological factors upon the magnesium deficiency syndrome. J. Nutr. 76:23.

Chiemchaisri, Y., and P. H. Phillips. 1963. Effect of dietary fluoride upon the magnesium calcinosis syndrome. J. Nutr. 81:307.

De Gubareff, N., and W. R. Platt. 1969. Influence of sodium fluoride on healing of experimental fractures. In rats, squirrel monkeys and dogs. Arch. Environ. Health 19:22.

Henrikson, P., L. Lutwak, L. Krook, R. Skogerboe, F. Kallfelz, L. F. Bélanger, J. R. Marier, B. E. Sheffy, B. Romanus, and C. Hirsch. 1970. Fluoride and nutritional osteoporosis: Physicochemical data on bones from an experimental study in dogs. J. Nutr. 100:631.

Krook, L. 1969. Metabolic bone diseases of endocrine origin, pp. 524–584. *In* Ernst Joests Handbuch der speziellen pathologischen Anatomie der Haustiere, vol. I. Paul Parey, Berlin and Hamburg.

Krook, L., L. Lutwak, P. Henrikson, F. Kallfelz, C. Hirsch, B. Romanus, L. F. Bélanger, J. R. Marier, and B. E. Sheffy. 1971. Reversibility of nutritional osteoporosis: Physicochemical data on bones from an experimental study in dogs. J. Nutr. 101:233.

VITAMINS

Vitamin A

Bradfield, D., and M. C. Smith. 1938. The ability of the dog to utilize vitamin A from plant and animal sources. Am. J. Physiol. 124:168.

Crimm, P. D., and D. M. Short. 1937. Vitamin A deficiency in the dog. Am. J. Physiol. 118:477.

Frohring, W. O. 1935. Vitamin A requirements of growing puppies. Proc. Soc. Exp. Biol. Med. 33:280.

Frohring, W. O. 1937a. Vitamins and distemper. II. Methods of study and preliminary experiments. Vet. Med. 32:76.

Frohring, W. O. 1937b. Vitamins and distemper. III. The symptoms of vitamin A deficiency. Vet. Med. 32:190.

Hendricks, J. B., A. F. Morgan, and R. M. Freytag. 1947. Chronic moderate hypervitaminosis D in young dogs. Am. J. Physiol. 149:319.

Kaspar, L. V., and L. S. Lombard. 1963. Nutritional myodegeneration in a litter of beagles. J. Am. Vet. Med. Assoc. 143: 284.

Keane, K. W., F. I. Nakamura, and M. L. Morris. 1947. Vitamin A plasma levels of dogs. North Am. Vet. 28:587.

Krause, R. F., and P. A. Brown. 1967. Effect of atherosclerosis and vitamin A on glucose tolerance in dogs. Proc. Soc. Exp. Biol. Med. 125:896.

Krause, R. F., M. A. Pallotta, and I. I. Yoder. 1968. Lipid alterations in beagles produced by atherogenic stress and vitamin A. J. Atherosclerosis Res. 8:277.

Maddock, C. L., S. B. Wolbach, and S. Maddock. 1949. Hypervitaminosis A in the dog. J. Nutr. 39:117.

Martin, C. L. 1971. Effect of topical vitamin A, antibiotic, mineral oil, and subconjunctival corticosteroid on corneal epithelial wound healing in the dog. J. Am. Vet. Med. Assoc. 159:1392.

Mellanby, E. 1920. Accessory food factors (vitamins) in the feeding of infants. Lancet 1:856.

Mellanby, E. 1938. The experimental production of deafness in young animals by diet. J. Physiol. 94:380.

Michaud, L., and C. A. Elvehjem. 1944. The nutritional requirements of the dog. North Am. Vet. 25:657.

Morgan, A. F., and L. S. Bentley. 1943. The excretion of vitamin A in dog urine. Fed. Proc. 2:67.

Russell, W. C., and M. L. Morris. 1939. Vitamin A deficiency in the dog. 1. Experimental production of the vitamin A deficient condition. J. Am. Vet. Med. Assoc. 95:316.

Singh, M. M., G. K. Sinha, and B. N. Gupta. 1965. Corneal opacity in a dog. Indian Vet. J. 42:879.

Steenbock, H., E. M. Nelson, and E. B. Hart. 1921. Fat soluble vitamine. IX. The incidence of an ophthalmic reaction in dogs fed a fat soluble vitamine deficient diet. Am. J. Physiol. 58:14.

Stimson, A. M., and O. F. Hedley. 1933. Observations on vitamin A deficiency in dogs. U.S. Public Health Rep. 48:445.

Turner, R. G. 1934. Effect of prolonged feeding of raw carrots on vitamin A content of liver and kidneys in the dog. Proc. Soc. Exp. Biol. Med. 31:866.

Wakerlin, G. E., W. G. Moss, and E. L. Smith. 1942. Treatment of experimental renal hypertension with vitamin A. Science 96:161.

Wiersig, D. O., and M. J. Swenson. 1967. Teratogenicity of vitamin A in the canine. Fed. Proc. 26:486.

Vitamin D

Arnold, A., and C. A. Elvehjem. 1939. Nutritional requirements of dogs. J. Am. Vet. Med. Assoc. 95:187.

Campbell, J. R., and T. A. Douglas. 1965. The effect of low calcium intake and vitamin D supplements on bone structure in young growing dogs. Br. J. Nutr. 19:339.

Fleischmann Laboratories. 1940. Amounts of supplementary vitamin D suggested for feeds for four-footed animals. Vitamin D Digest 2:7.

Hendricks, J. B., A. F. Morgan, and R. M. Freytag. 1947. Chronic moderate hypervitaminosis D in young dogs. Am. J. Physiol. 149:319.

Kozelka, F. L., E. B. Hart, and G. Bohstedt. 1933. Growth, reproduction, and lactation in the absence of the parathyroid glands. J. Biol. Chem. 100:715.

Lam, H.-Y., H. K. Schnoes, H. F. DeLuca, and T. C. Chen. 1973. 24,25-dihydroxyvitamin D_3. Synthesis and biological activity. Biochem. 12:4851.

McCay, C. M. 1949. Nutrition of the dog. Comstock Publishing Company, Ithaca, N. Y.

Michaud, L., and C. A. Elvehjem. 1944. The nutritional requirements of the dog. North Am. Vet. 25:657.

Morgan, A. F., and N. Shimotori. 1943. The absorption and retention by dogs of single massive doses of various forms of vitamin D. J. Biol. Chem. 147:189.

Morgan, A. F., H. E. Axelrod, and M. Groody. 1947. The effect of a single massive dose of vitamin D_2 on young dogs. Am. J. Physiol. 149:333.

Ney, R. L., G. Kelly, and F. C. Bartter. 1968. Actions of vitamin D independent of the parathyroid glands. Endocrinology 82:760.

Omdahl, J. L., and H. F. DeLuca. 1973. Regulation of vitamin D metabolism and function. Physiol. Rev. 53:327.

Schaefer, A. E. 1954. The nutritional requirements of dogs, pp. 29–36. Tex. Nutr. Conf.

Wasserman, R. H. 1970. The vitamin D-dependent calcium-binding protein, pp. 21–38. *In* H. F. DeLuca and J. W. Suttie [ed.] The fat-soluble vitamins. University of Wisconsin Press, Madison.

Wheatley, V. R., and D. W. Sher. 1961. Studies of the lipids of dog skin. I. The chemical composition of dog skin lipids. J. Invest. Derm. 36:169.

Vitamin E

Anderson, H. D., C. A. Elvehjem, and J. E. Gonce, Jr. 1939. Vitamin E deficiency in dogs. Proc. Soc. Exp. Biol. Med. 42:750.

Anderson, H. D., C. A. Elvehjem, and J. E. Gonce, Jr. 1940. A comparison of the nutritive values of raw, pasteurized and evaporated milks for the dog. J. Nutr. 20:433.

Bieri, J. G., and R. P. Evarts. 1973. Tocopherols and fatty acids in American diets. J. Am. Dietet. Assoc. 62:147.

Brinkhous, K. M., and E. D. Warner. 1941. Muscular dystrophy in biliary fistula dogs: Possible relationship to vitamin E deficiency. Am. J. Pathol. 17:81.

Chow, C. K., and A. L. Tappel. 1974. Response of glutathione peroxidase to dietary selenium in rats. J. Nutr. 104:444.

Cordes, D. O., and A. H. Mosher. 1966. Brown pigmentation (lipofuscinosis) of canine intestinal muscularis. J. Pathol. Bacteriol. 92:197.

Elvehjem, C. A., J. E. Gonce, Jr., and G. W. Newell. 1944. The effect of vitamin E on reproduction in dogs on milk diets. J. Pediatr. 24:436.

Harris, P. L., and N. D. Embree. 1963. Quantitative consideration of the effect of polyunsaturated fatty acid content of the diet upon the requirements for vitamin E. Am. J. Clin. Nutr. 13:385.

Hayes, K. C., S. W. Nielsen, and J. E. Rousseau, Jr. 1969. Vitamin E deficiency and fat stress in the dog. J. Nutr. 99: 196.

Hayes, K. C., and J. E. Rousseau. 1970. Dialuric acid hemolysis as an index of plasma tocopherol concentrations in the dog. Lab. Anim. Care 20:48.

Hayes, K. C., J. E. Rousseau, Jr., and D. M. Hegsted. 1970. Plasma tocopherol concentrations and vitamin E deficiency in dogs. J. Am. Vet. Med. Assoc. 157:64.

Kaspar, L. V., and L. S. Lombard. 1963. Nutritional myodegeneration in a litter of beagles. J. Am. Vet. Med. Assoc. 143:284.

March, B. E., E. Wong, L. Seier, J. Sim, and J. Biely. 1973. Hypervitaminosis E in the chick. J. Nutr. 103:371.

Nachtnebel, E. 1933. Pigment deposits in intestinal muscle coats and their relation to diet factors. Am. J. Pathol. 9:261.

Pappenheimer, A. M., and J. Victor. 1946. Ceroid pigment in human tissues. Am. J. Pathol. 22:395.

Schaefer, A. E. 1954. The nutritional requirements of dogs, pp. 26–36. Tex. Nutr. Conf.

Schwarz, K., and C. M. Foltz. 1957. Selenium as an integral part of factor-3 against necrotic liver degeneration. J. Am. Chem. Soc. 79:3293.

Van Kruiningen, J. J. 1967. Granulomatous colitis of boxer dogs: Comparative aspects. Gastroenterology 53:114.

Van Vleet, J. 1972. Personal communication. Purdue University, Lafayette, Indiana.

Vitamin K

Anderson, G. F., and M. I. Barnhart. 1964. Prothrombin synthesis in the dog. Am. J. Physiol. 206:929.

Barnhart, M. I., G. F. Anderson, and M. H. Bernstein. 1964. Liver ultrastructure after coumarin and vitamin K_1. Fed. Proc. 23: 520.

Bratt, H. M., H. M. Bratt, and E. Bratt. 1965. Suspected vitamin K deficiency in newborn pups. J. Am. Vet. Med. Assoc. 146:1053.

Clark, W. T., and R. E. W. Halliwell. 1963. The treatment with vitamin K preparations of warfarin poisoning in dogs. Vet. Rec. 75:1210.

Duello, T. J., and J. T. Matschiner. 1971a. The relationship between the storage forms of vitamin K and dietary phylloquinone in the dog. Int. J. Vitamin Nutr. Res. 41:180.

Duello, T. J., and J. T. Matschiner. 1971b. Characterization of vitamin K from pig liver and dog liver. Arch. Biochem. Biophys. 144:330.

Dulock, M. A., and S. N. Kolmen. 1968. Influence of vitamin K on restoration of prothrombin complex proteins and fibrinogen in plasma of depleted dogs. Thromb. Diathesis Haemorrhagica 20:136.

Hayes, K. C., and D. M. Hegsted. 1973. Toxicity of the vitamins, pp. 235–253. *In* Toxicants occurring naturally in foods. National Academy of Sciences, Washington, D. C.

Quick, A. J., C. V. Hussey, and G. E. Collentine, Jr. 1954. Vitamin K requirements of adult dogs and the influence of bile on its absorption from the intestine. Am. J. Physiol. 176:239.

Quick, A. J., G. E. Collentine, Jr., and C. V. Hussey. 1962. Vitamin K requirements of the growing pup. J. Nutr. 77:28.

Reber, E. F., and O. P. Malhotra. 1961. Effects of feeding a vitamin K-deficient ration containing irradiated beef to rats, dogs and cats. J. Nutr. 74:191.

Robinson, H. J., K. L. Kelley and E. G. Lehman. 1964. Effect of cholestyramine, a bile acid binding polymer, on vitamin K_1 absorption in dogs. Proc. Soc. Exp. Biol. Med. 115:112.

Thiamin

Arnold, A., and C. A. Elvehjem. 1939a. Influence of the composition of the diet on the thiamin requirement of dogs. Am. J. Physiol. 126:289.

Arnold, A., and C. A. Elvehjem. 1939b. Nutritional requirements of dogs. J. Am. Vet. Med. Assoc. 95:187.

Brin, M., and W. A. Vincent. 1965. The diagnosis of thiamine adequacy in the dog by use of the erythrocyte enzyme, transketolase. J. Am. Vet. Med. Assoc. 147:1649.

Cowgill, G. R. 1921. A contribution to the study of the relation between vitamin-B and the nutrition of the dog. Am. J. Physiol. 57: 420.

Cowgill, G. R. 1934. The vitamin B requirement of man. Yale University Press, New Haven, Conn.

da Silva, A. C., and A. C. Ivy. 1961. Absorption of thiamine from intestine of dog. Am. J. Physiol. 201:185.

Davis, J. S., and J. C. Somogyi. 1969. Reaction mechanism of the inactivation of thiamine by 3,4-dihydroxycinnamic acid. Int. J. Vitamin Res. 31:16.

Drill, V. A. 1941. The calorie intake and weight balance of hyperthyroid dogs in relation to vitamin B_1 and yeast. Am. J. Physiol. 132:629.

Drill, V. A., and H. W. Hays. 1942. Studies on the relation of the liver function, pulse rate and temperature of hyperthyroid dogs to vitamin B_1 and yeast. Am. J. Physiol. 136: 762.

Drill, V. A., and C. B. Shaffer. 1942. Effect of vitamin B_1 and yeast on calorie intake and weight balance of hyperthyroid dogs. Endocrinology 31:567.

Green, R. G. 1936. Chastek paralysis—A new disease of foxes. Minn. Wildl. Dis. Inv. 2:106.

Karr, W. G. 1920. Some effects of water-soluble vitamins upon nutrition. J. Biol. Chem. 44:255.

Lavers, M. K., P. A. Stefanik, and C. F. Code. 1959. Effect of thiamine deficiency on canine gastric secretion of acid. Am. J. Physiol. 197:253.

Maass, A. R., L. Michaud, H. Spector, C. A. Elvehjem, and E. B. Hart. 1944. The relation of thiamine to blood regeneration. Arch. Biochem. Biophys. 4:105.

Malnic, G., A. C. da Silva, R. C. de Angelis, and Z. J. Gomes. 1960. Renal excretion of thiamin by the dog. Am. J. Physiol. 198:1274.

Malnic, G., M. R. E. Silva, Jr., R. C. de Angelis, and A. C. da Silva. 1962. Simultaneous excretion of thiamine and thiamine phosphates by the dog. Am. J. Physiol. 202:1109.

Martin, C. L. 1971. Thiamin deficiency in the dog and cat, pp. 69–70. *In* R. W. Kirk [ed.] Current veterinary therapy IV. Small animal practice. W. B. Saunders and Company, Philadelphia.

Noel, P. R. B., H. Chesterman, D. W. Jolly, and H. Partington. 1971. Thiamine (vitamin B_1) supplementation in the dog. Vet. Rec. 89:260.

Petrovaskaja, N. I. 1958. Conditioned alimentary salivation reflexes in puppies, normal and deprived of vitamin B_1. Fiziol. Z. SSSR Secenova 44:202. Nutr. Abstr. Rev. 29:82 (1959).

Street, H. R., H. M. Zimmerman, G. R. Cowgill, H. E. Hoff, and J. C. Fox, Jr. 1941. Some effects produced by long-continued subminimal intakes of vitamin B_1. Yale J. Biol. Med. 13:293.

Unna, K. R. 1954. Thiamine XI. Pharmacology, pp. 466–471. *In* W. H. Sebrell, Jr., and R. S. Harris [ed.] The vitamins, vol. III. Academic Press, Inc., N. Y.

Voegtlin, C., and G. C. Lake. 1919. Experimental mammalian polyneuritis produced by a deficient diet. Am. J. Physiol. 47:558.

Riboflavin

Axelrod, A. E., M. A. Lipton, and C. A. Elvehjem. 1939–1940. The production of uncomplicated riboflavin deficiency in the dog. Am. J. Physiol. 128:703.

Axelrod, A. E., M. A. Lipton, and C. A. Elvehjem. 1941. Riboflavin deficiency in the dog. Am. J. Physiol. 133:555.

Heywood, R., and H. Partington. 1971. Ocular lesions induced by vitamin B_2 deficiency. Vet. Rec. 88:251.

Jusko, W. J., B. R. Rennick, and G. Levy. 1970. Renal excretion of riboflavin in the dog. Am. J. Physiol. 218:1046.

Noel, P. R. B., H. Chesterman, R. Heywood, and D. W. Jolly. 1972. Riboflavin supplementation in the dog. Res. Vet. Sci. 13: 443.

Potter, R. L., A. E. Axelrod, and C. A. Elvehjem. 1942. The riboflavin requirement of the dog. J. Nutr. 24:449.

Spector, H., A. R. Maass, L. Michaud, C. A. Elvehjem, and E. B. Hart. 1943. The role of riboflavin in blood regeneration. J. Biol. Chem. 150:75.

Street, H. R., and G. R. Cowgill. 1939. Acute riboflavin deficiency in the dog. Am. J. Physiol. 125:323.

Street, H. R., G. R. Cowgill, and H. M. Zimmerman. 1941. Further observations of riboflavin deficiency in the dog. J. Nutr. 22:7.

Pantothenic Acid

Das, K. M. 1962. Experimental pantothenic acid deficiency in dogs, a pathologic-anatomic study. Diss. Abstr. 23:205.

Fouts, P. J., O. M. Helmer, and S. Lepkovsky. 1940. Factor II deficiency in dogs. J. Nutr. 19:393.

Gantt, W. H., B. F. Chow, and M. Simonson. 1959. Effect of pyridoxine and pantothenic acid deficiency on conditional reflexes. Am. J. Clin. Nutr. 7:411.

McKibbin, J. M., R. J. Madden, S. Black, and C. A. Elvehjem. 1939-1940. The importance of vitamin B_6 and factor W in the nutrition of dogs. Am. J. Physiol. 128:102.

McKibbin, J. M., S. Black, and C. A. Elvehjem. 1940. The essential nature of pantothenic acid and another alkali-labile factor in the nutrition of the dog. Am. J. Physiol. 130:365.

Morgan, A. F., and H. D. Simms. 1940. Greying of fur and other disturbances in several species due to a vitamin deficiency. J. Nutr. 19:233.

Schaefer, A. E., J. M. McKibbin, and C. A. Elvehjem. 1942. Pantothenic acid deficiency studies in dogs. J. Biol. Chem. 143:321.

Scudi, J. V., and M. Hamlin. 1942. The effect of pantothenic acid deficiency on the blood lipids of the dog. J. Nutr. 24:273.

Sheffy, B. E. 1964. Nutrient requirements of dogs. pp. 159–162. Cornell Nutr. Conf., Cornell University, Ithaca, N. Y.

Silber, R. H. 1944. Studies of pantothenic acid deficiency in dogs. J. Nutr. 27:425.

Taylor, T., D. R. Hawkins, D. E. Hathway, and H. Partington. 1972. A new urinary metabolite of pantothenate in dogs. Br. Vet. J. 128:500.

Niacin (Nicotinic Acid and Nicotinamide)

Afonsky, D. 1954. A study of experimental vitamin B complex deficiency in adult dogs: Oral lesions, blood changes and gastrointestinal activity in niacin, riboflavin, pyridoxine, folic acid, and pantothenic acid deficiencies. Ph.D. Thesis, University of Rochester (New York).

Belavady, B., and C. Gopalan. 1965. Production of black tongue in dogs by feeding diets containing jowar (*Sorghum vulgare*). Lancet 2:1220.

Belavady, B., and C. Gopalan. 1966. Availability of nicotinic acid in jowar (*Sorghum vulgare*). Indian J. Biochem. Biophys. 3:44.

Belavady, B., T. V. Madhavan, and C. Gopalan. 1967. Production of nicotinic acid deficiency (blacktongue) in pups fed diets supplemented with leucine. Gastroenterology 53: 749.

Birch, T. W. 1939. The requirements of the dog and the rat for nicotinic acid. J. Nutr. 17:281.

Dann, W. J., and P. Handler. 1941. The nicotinic acid and coenzyme content of the tissues of normal and blacktongue dogs. J. Nutr. 22:409.

Dann, W. J., H. I. Kohn, and P. Handler. 1940. The effect of pyrazine acids and quinolinic acid on the V-factor content of human blood and upon canine blacktongue. J. Nutr. 20: 477.

Efremov, V. V., A. I. Makarychev, and A. N. Tikhomirova. 1954. Effect of niacin avitaminosis on conditioned reflexes in dogs. Voprosy Pitaniya 13:10 (Chem. Abstr. 49:11800, 1955).

Elvehjem, C. A., R. J. Madden, F. M. Strong, and D. W. Woolley. 1937. Relation of nicotinic acid and nicotinic acid amide to canine black tongue. J. Am. Chem. Soc. 59:1767.

Elvehjem, C. A., R. J. Madden, F. M. Strong, and D. W. Woolley. 1938. The isolation and identification of the anti-black tongue factor. J. Biol. Chem. 123:137.

Ghosh, H. P., P. K. Sarkar, and B. C. Guha. 1963. Distribution of the bound form of nicotinic acid in natural materials. J. Nutr. 79:451.

Goldberger, J., and G. A. Wheeler. 1920. Experimental pellagra in white male convicts. Arch. Intern. Med. 25:451.

Goldberger, J., and G. A. Wheeler. 1928. Experimental black tongue of dogs and its relation to pellagra. Public Health. Rep. 43:172.

Grande, F., and D. S. Amatuzio. 1960. Nicotinic acid and serum cholesterol in the dog. Fed. Proc. 19:237.

Grande, F. 1966. Effect of nicotinic acid on the serum lipids of normal and of thyroidectomized dogs. Metabolism 15: 661.

Greengard, P., E. B. Sigg, I. Fratta, and S. B. Zak. 1966. Prevention and remission by adrenocortical steroids of nicotinamide deficiency disorders and of 6-aminonicotinamide toxicity in rats and dogs. J. Pharm. Exp. Ther. 154:624.

Handler, P. 1943. Use of highly purified rations in the study of nicotinic acid deficiency. Proc. Soc. Exp. Biol. Med. 52:263.

Hankes, L. V., J. E. Leklem, R. R. Brown, and R. C. P. M. Mekel. 1971. Tryptophan metabolism in patients with pellagra: Problem of vitamin B_6 enzyme activity and feedback control of tryptophan pyrrolase enzyme. Am. J. Clin. Nutr. 24:730.

Kohn, H. I., J. R. Klein, and W. J. Dann. 1939. The V-factor content and oxygen consumption of tissues of the normal and blacktongue dog. Biochem. J. 33:1432.

Krehl, W. A., L. J. Teply, and C. A. Elvehjem. 1945. Effect of corn grits on nicotinic acid requirements of the dog. Proc. Soc. Exp. Biol. Med. 58:334.

Layne, J. A., and J. B. Carey. 1944. The effect of a black-tongue-producing diet upon the endoscopic appearance of the gastric mucosa in the dog. Gastroenterology 2:133.

Madhavan, T. V., B. Belavady, and C. Gopalan. 1968. Pathology of canine black tongue. J. Pathol. Bacteriol. 95:259.

Margolis, G., L. H. Maroglis, and S. G. Smith. 1938. Cure of experimental canine blacktongue with optimal and minimal doses of nicotinic acid. J. Nutr. 16:541.

Margolis, L. H., G. Margolis, and S. G. Smith. 1939. Secondary deficiency of vitamin B_1 and riboflavin in the blacktongue producing diet. J. Nutr. 17:63.

Nelson, R. A., C. F. Code, and A. L. Brown, Jr. 1962. Sorption of water and electrolytes, and mucosal structure, in niacin deficiency. Gastroenterology 42:26.

Pereira, J. N. 1967. The plasma free fatty acid rebound induced by nicotinic acid. J. Lipid Res. 8:239.

Pereira, J. N., and G. A. Mears. 1971. The biphasic effect of nicotinic acid on plasma FFA levels. Life Sci. 10 (1):1.

Sarett, H. P. 1942. Studies in nicotinic acid metabolism. II. The fate of nicotinic acid in normal and black tongue dogs. J. Nutr. 23:35.

Schaefer, A. E., J. M. McKibbin, and C. A. Elvehjem. 1942. Nicotinic acid deficiency studies in dogs. J. Biol. Chem. 144:679.

Sebrell, W. H., R. H. Onstott, H. F. Fraser, and F. S. Daft. 1938. Nicotinic acid in the prevention of blacktongue of dogs. J. Nutr. 16:355.

Singal, S. A., V. P. Sydenstricker, and J. M. Littlejohn. 1948. The role of tryptophan in the nutrition of dogs on nicotinic-acid deficient diets. J. Biol. Chem. 176:1051.

Smth, S. G., R. Curry, and H. Hawfield. 1943. Nicotinic acid storage in the dog at different dose levels of the vitamin. J. Nutr. 25:341.

Street, H. R., and G. R. Cowgill. 1937. The cure of canine blacktongue with nicotinic acid. Proc. Soc. Exp. Biol. Med. 37:547.

West, R. 1941. Inhibition by sulfapyridine of the curative action of nicotinic acid in dogs. Proc. Soc. Exp. Biol. Med. 46:369.

Zanetti, M. E., and D. M. Tennent. 1963. Hormonal hypercholesterolemia in the dog: Influence of niacin, nicinamide, benzmalecene, and chloestyramine resin. Proc. Soc. Exp. Biol. Med. 112:991.

Vitamin B_6 (Pyridoxine, Pyridoxal, and Pyridoxamine)

Axelrod, H. E., A. F. Morgan, and S. Lepkovsky. 1945. The fate of trytophane in pyridoxine-deficient and normal dogs. J. Biol. Chem. 160:155.

Borson, H. J., and S. R. Mettier. 1940. Relief of hypochromic anemia in dogs with synthetic vitamin B_6. Influence of "filtrate factors." Proc. Soc. Exp. Biol. Med. 43:429.

Eremeev, V. S. 1968. Effect of vitamin B_6 on the toxic effects of strophanthin. Farmakol. Toksikol. 31:88.

Fisher, B., S. H. Lee and E. R. Fisher. 1963. Effect of pyridoxine deficiency on renal homotransplantation in puppies. Surgery 54:784.

Fouts, P. J., O. M. Helmer, S. Lepkovsky, and T. H. Jukes. 1938. Production of microcytic hypochromic anemia in puppies on synthetic diet deficient in rat anti-dermatitis factor (vitamin B_6). J. Nutr. 16:197.

Fouts, P. J., O. M. Helmer, and S. Lepkovsky. 1939. Cure of microcytic hypochromic anemia in dogs with crystalline "factor 1." Proc. Soc. Exp. Biol. Med. 40:4.

Gantt, W. H., B. F. Chow, and M. Simonson. 1959. Effect of pyridoxine and pantothenic acid deficiency on conditional reflexes. Am. J. Clin. Nutr. 7:411.

Humphries, Jr., A. L., W. S. Harms, and W. H. Moretz. 1961. Skin homografts in dogs deficient in pyridoxine. J. Am. Med. Assoc. 178:150.

Klosterman, H. J., G. L. Lamoureux, and J. L. Parsons. 1967. Isolation, characterization and synthesis of linatine. A vitamin B_6 antagonist from flaxseed (*Linum usitatissimum*). Biochem. 6:170.

McKibbin, J. M., R. J. Madden, S. Black, and C. A. Elvehjem. 1939–1940. The importance of vitamin B_6 and factor W in the nutrition of logs. Am. J. Physiol. 128:102.

McKibbin, J. M., A. E. Schaefer, D. V. Frost, and C. A. Elvehjem. 1942. Studies on anemia in dogs due to pyridoxine deficiency. J. Biol. Chem. 142:77.

Michaud, L., and C. A. Elvehjem. 1944. The nutritional requirements of the dog. North Am. Vet. 25:657.

Söderhjelm, L. 1962. Influence of pyridoxine and dietary fat on the distribution of serum fatty acids in dogs. J. Nutr. 78:438.

Street, H. R., G. R. Cowgill, and H. M. Zimmerman. 1941. Some observations of vitamin B_6 deficiency in the dog. J. Nutr. 21:275.

Ullrich, W. 1967. "Castrix" poisoning in small animals. Wiener Tierärzt. Monatsschrift 54:486.

Folacin (Folic Acid and Derivatives)

Afonsky, D. 1954. Folic acid deficiency in the dog. Science 120:803.

Goresky, C. A., H. Watanabe, and D. G. Johns. 1963. The renal excretion of folic acid. J. Clin. Invest. 42:1841.

Krehl, W. A., and C. A. Elvehjem. 1945. The importance of folic acid in rations low in nicotinic acid. J. Biol. Chem. 158:173.

Krehl, W. A., N. J. Torbet, J. de la Huerga, and C. A. Elvehjem. 1946. Relation of folic acid to niacin deficiency in dogs. Arch. Biochem. 11:363.

Luketic, G. C., R. Santini, Jr., and C. E. Butterworth, Jr. 1965. Depression of whole blood folate activity by cholchicine. Proc. Soc. Exp. Biol. Med. 120:13.

Ruegamer, W. R., W. L. Brickson, N. J. Torbet, and C. A. Elvehjem. 1948. Response of dogs to liver extracts containing the pernicious anemia factor. J. Nutr. 36:425.

Schaefer, A. E. 1954. The nutritional requirements of the dog, pp. 29–36. Tex. Nutr. Conf.

Sheffy, B. E. 1964. Nutrient requirements of dogs, pp. 159–162. Cornell Nutr. Conf. Cornell University, Ithaca, N. Y.

Vogel, W. H., R. Snyder, and M. P. Schulman. 1964. Inhibition of alcohol dehydrogenase by folic acid and several of its analogs. Proc. Soc. Exp. Biol. Med. 115:545.

Biotin

Green, N. M. 1963. Avidin. III. The nature of the biotin-binding site. Biochem. J. 89:599.

Greve, J. H. 1963. Effects of thyroid and biotin deficiencies on canine demodicosis. Diss. Abstr. 24:1757.

Hertz, R., and W. H. Sebrell. 1942. Occurrence of avidin in the oviduct and secretions of the genital tract of several species. Science 96:257.

National Research Council. 1971. Nutrient requirements of poultry. National Academy of Sciences, Washington, D. C.

Siegel, S., W. E. Nixon, and F. G. Dhyse. 1967. Distribution of biotin and tritiated biotin in maternal, prenatal and postnatal dog tissues. Growth 31:61.

Wei, R. D., and L. D. Wright. 1964. Heat stability of avidin and avidin-biotin complex and influence of ionic strength on affinity of avidin for biotin. Proc. Soc. Exp. Biol. Med. 117:341.

Vitamin B_{12}

Arnrich, L., E. M. Lewis, and A. F. Morgan. 1952. Growth of dogs on purified diet plus aureomycin and/or vit. B_{12}. Proc. Soc. Exp. Biol. Med. 80:401.

Bryant, Jr., J. A., and E. S. Stafford. 1965. Vitamin B_{12} absorption in dogs as measured by the isolated intestinal loop technique. Bull. Johns Hopkins Hosp. 116:341.

Cooperman, J. M., A. L. Luhby, D. N. Tellar, and J. F. Marley. 1960. Distribution of radioactive and nonradioactive vitamin B_{12} in the dog. J. Biol. Chem. 235:191.

Coppi, G., L. Monti, and R. Genova. 1970. Blood levels and urinary excretion of three vitamins B_{12} in rat, rabbit and dog. Soc. Ital. Biol. Sper. 46:312.

Fleming, W. H., E. R. King, R. A. Galloway, and J. J. Roche. 1962. The site of absorption of orally administered Co^{60}-labeled vitamin B_{12} in dogs: The effect of dose. Gastroenterology 42:164.

Gazet, J.-C., and I. McColl. 1967. Absorption of vitamin B_{12} from the small intestine. Study in man, monkey, cat, and dog. Br. J. Surg. 54:128.

Hermann, G., H. K. Axtell, and T. E. Starzl. 1964. Bacterial contamination of the jejunum and vitamin B_{12} absorption. Gastroenterology 47:61.

Lavrova, V. S. 1969. Effect of prolonged absence of bile from the intestine on vitamin B_{12} metabolism and the state of the blood system. Byull. Eksper. Biol. Medit. 67:29.

Markelova, V. F. 1960. The effect of denervation of the spleen on the serum vitamin B_{12} level in dogs. Bull. Exp. Biol. Med. 49:137.

National Research Council. 1973. Nutrient requirements of swine. National Academy of Sciences, Washington, D. C.

Nelp, W. B., H. N. Wagner, Jr., R. C. Reba, P. G. Dennis, and R. E. Bower. 1964. Renal excretion of vitamin B_{12} and its use in measurement of glomerular filtration rate in man. J. Lab. Clin. Med. 63:480.

Pshonik, A. T., and A. A. Gribanov. 1961. The effect of vitamin B_{12} on the conditioned reflex activity of dogs. Zh. Vyssh. Nervn, deyatel. 11:1026.

Rappazzo, M. E., and C. A. Hall. 1972. Cyanocobalamin transport proteins in canine plasma. Am. J. Physiol. 222: 202.

Reizenstein, P. G., E. P. Cronkite, L. M. Meyer, E. A. Usenik, and D. Driscoll. 1960. Lymphatics in intestinal absorption of vitamin B_{12} and iron. Proc. Soc. Exp. Biol. Med. 105: 233.

Rosenblum, C., P. G. Reizenstein, E. P. Cronkite, and H. T. Meriwether. 1963. Tissue distribution and storage forms of vitamin B_{12} injected and orally administered to the dog. Proc. Soc. Exp. Biol. Med. 112:262.

Skeggs, H. R., R. E. Zwickey, J. L. Stanley, G. C. Shurr, and A. Phelps. 1963. Vitamin B_{12} and folic acid. Fed. Proc. 22:203.

Sonneborn, D. W., G. Abouna, and G. Mendez-Picon. 1972. Synthesis of transcobalamin II in totally hepatectomized dogs. Biochem. Biophys. Acta 273:283.

Taylor, R. M., J. A. Hildes, and J. F. Lind. 1969. Vitamin B_{12} absorption in dogs with chronic isolated intestinal loops. Can. J. Physiol. Pharm. 47:497.

Weisberg, H., J. Rhodin, and G. B. Jerzy Glass. 1968. Intestinal vitamin B_{12} absorption in the dog. III. Demonstration of the intracellular pathway of absorption by light and electron microscope autoradiography. Lab. Invest. 19:516.

Weisberg, H., and J. Rhodin. 1970. Relation of calcium to mucosal structure and vitamin B_{12} absorption in the canine intestine. Am. J. Pathol. 61:141.

Woods, W. D., W. B. Hawkins, and G. H. Whipple. 1960. Vitamin B_{12} Co^{60} readily passes the placenta into fetal organs and nursing provides B_{12} from mother to pup. J. Exp. Med. 112:431.

Yamaguchi, N., H. Weisberg, and G. B. Jerzy Glass. 1969a. Intestinal vitamin B_{12} absorption in the dog. I. Evidence against an intrinsic factor mechanism for vitamin B_{12} absorption. Gastroenterology 56:914.

Yamaguchi, N., H. Weisberg, and G. B. Jerzy Glass. 1969b. Intestinal vitamin B_{12} absorption in the dog. II. Characterization of vitamin B_{12} binders in dog gastrointestinal mucosae and secretions. Gastroenterology 56:925.

Choline

Acara, M., and B. Rennick. 1973. Regulation of plasma choline by the renal tubule:Bidirectional transport of choline. Am. J. Physiol. 225:1123.

Anonymous. 1945a. Choline deficiency studies in dogs. Nutr. Rev. 3:124.

Anonymous. 1945b. Liver function and experimental choline deficiency in dogs. Nutr. Rev. 3:261.

Best, C. H., G. C. Ferguson, and J. M. Hershey. 1933. Choline and liver fat in diabetic dogs. J. Physiol. 79:94.

Chaikoff, I. L., and A. Kaplan. 1937. On the survival of the completely depancreatinized dog. J. Nutr. 14:459.

Di Luzio, N. R., and D. B. Zilversmit. 1959. Effect of single and chronic choline supplementation on phospholipid metabolism of the dog. Am. J. Physiol. 196:887.

Dutra, F. R., and J. M. McKibbin. 1945. The pathology of experimental choline deficiency in dogs. J. Lab. Clin. Med. 30:301.

Fouts, P. J. 1943. Vitamin B complex studies in dogs: Production of cirrhosis of liver. J. Nutr. 25:217.

McKibbin, J. M., S. Thayer, and F. J. Stare. 1944. Choline deficiency studies in dogs. J. Lab. Clin. Med. 29:1109.

McKibbin, J. M., R. M. Ferry, Jr., S. Thayer, E. G. Patterson, and F. J. Stare. 1945. Further studies on choline deficiency in dogs. J. Lab. Clin. Med. 30:422.

Schaefer, A. E., J. M. McKibbin, and C. A. Elvehjem. 1941. Importance of choline in synthetic rations for dogs. Proc. Soc. Exp. Biol. Med. 47:365.

Solomon, S. 1966. Urinary alkalinization induced by choline. Arch. Int. Physiol. 74:73.

Vitamin C (Ascorbic Acid)

Belfield, W. O. 1967. Vitamin C in treatment of canine and feline distemper complex. Vet. Med. Small Anim. Clin. 62: 345.

Bendefy, A. A. 1965. Recovery from barbiturate anaesthesia in whippets. Vet. Rec. 77:121.

Csaba, B., and S. Toth. 1966. The effect of ascorbic acid on anaphylactic shock in dogs. J. Pharm. Pharmacol. 18:325.

Ditchfield, J., and M. H. Phillipson. 1960. Achlorhydria in dogs, with report of a case complicated by avitaminosis C. Can. Vet. J. 1:396.

Garlick, N. L. 1946. True scurvy in the dog. J. Am. Vet. Med. Assoc. 109:70.

Holmes, J. R. 1962. Suspected skeletal scurvy in the dog. Vet. Rec. 74:801.

Hunt, G. C. 1962. Suspected skeletal scurvy in the dog. Vet. Rec. 74:1109.

Innes, J. R. M. 1931. Vitamin C requirements of the dog: Attempts to produce experimental scurvy. 2d Rep. Dir. Camb. Inst. Anim. Pathol., p. 143.

Kleit, S., D. Levin, T. Perenich, and R. Cade. 1965. Renal excretion of ascorbic acid by dogs. Am. J. Physiol. 209:195.

Leveque, J. I. 1969. Ascorbic acid treatment of the canine distemper complex. Vet. Med. Small Anim. Clin. 64:997.

Majumdar, M. K., C. Sinha, and S. Lahiri. 1964. Transport form of vitamin C in mammals. Indian J. Exp. Biol. 2:224.

Meier, H., S. T. Clark, G. B. Schnelle and D. H. Will. 1957. Hypertrophic osteodystrophy associated with disturbance of vitamin C synthesis in dogs. J. Am. Vet. Med. Assoc. 130: 483.

Naismith, D. J. 1958. Ascorbic-acid requirements of the dog. Proc. Nutr. Soc. 17:xlii.

Naismith, D. J., and P. L. Pellett. 1960. The water-soluble vitamin content of blood serum and milk of the bitch. Proc. Nutr. Soc. 19:xi.

Sadek, S. E. 1962. Suspected skeletal scurvy in the dog. Vet. Rec. 74:905.

Sheffy, B. E. 1972. Nutrition and infection, pp. 55–61. *In* Canine Nutrition. University of Pennsylvania, Philadelphia. J. Nutr. 48:81.

WATER

Gaebler, O. H., and H. C. Choitz. 1964. Studies of body water and water turnover determined with deuterium oxide added to food. Clin. Chem. 10:13.

COMPOSITION OF FEEDS

Harris, L. E., J. M. Asplund, and E. W. Crampton. 1968. An international feed nomenclature and methods for summarizing and using feed data to calculate diets. Utah Agric. Exp. Stn. Bull. No. 479.

FORMULATED DIETS FOR DOGS (TABLE 11)

Campbell, J. E., and P. H. Phillips. 1953. Some problems on feeding fat to dogs. Southwest. Vet. 6:173.

Federal Specification N-F-170. 1966. Feed, dry, for dogs. September 6. U.S. Government Printing Office, Washington, D. C.

Goddard, K. M., G. D. Williams, P. M. Newberne, and R. B. Wilson. 1970. A comparison of all-meat, semi-moist and dry-type dog foods as diets for growing beagles. J. Am. Vet. Med. Assoc. 157:1233.

Gorham, J. R., J. C. Peckham, and J. Alexander. 1970. Rickets and osteodystrophia fibrosa in foxes fed a high horse-meat ration. J. Am. Vet. Med. Assoc. 156:1331.

Hartley, W. J., J. C. Kater, and A. Mackay. 1963. Goitre and low copper status in a litter of meat fed puppies. New Zealand Vet. J. 11:1.

Morris, M. L., Jr., S. M. Teeter, and D. R. Collins. 1971. The effects of the exclusive feeding of an all-meat dog food. J. Am. Vet. Med. Assoc. 158:477.

Seidler, A. J., and B. S. Schweigert. 1952. Effect of the level of fat in the diet on the growth performance of dogs.