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Committee on Animal Nutrition
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This report has been reviewed by a group other than the authors according to procedures approved by a Report Review Committee consisting of members of the National Academy of Sciences, the National Academy of Engineering, and the Institute of Medicine.

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Preface

This report contains information on the nutritional requirements, signs of deficiencies, growth rates, and feed and water requirements of different classes of poultry. Since the publication of the first report in 1944 in the series *Nutrient Requirements of Domestic Animals*, which was entitled *Recommended Nutrient Allowances of Poultry*, the subcommittees responsible for successive revisions have included many early references to data of historic interest dealing with the discovery of nutrient requirements. The subcommittee responsible for the eighth revision decided, with some regret, to delete these early references. References regarding most nutrients have been updated to emphasize data obtained with modern genetic stock and with diets formulated according to current knowledge. The information presented should be useful for those concerned with formulation and manufacturing of poultry diets and for students and teachers of poultry nutrition. The hope is that investigators in poultry research and agencies contributing research support will note areas where information is insufficient to allow a statement of nutrient requirements.

To all individuals who contributed to this manuscript, the subcommittee expresses appreciation. In particular, the subcommittee expresses its thanks to C. Wendell Carlson, Steven Leeson, G. E. Poley, and Joseph H. Soares, Jr., who reviewed the report and provided insightful comments and suggestions for the subcommittee's consideration.

Review of this report was accomplished through the advice and guidance of the members of the Committee on Animal Nutrition. The subcommittee is indebted to Philip Ross and Selma P. Baron of the Board on Agriculture for their assistance in the preparation of this report. The subcommittee is especially grateful to Robert H. Harms, who served as coordinator for the Board on Agriculture for the review of this report.

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1 Introduction

In establishing values for the requirements of poultry for the various nutrients, the subcommittee has reviewed and evaluated published results of nutritional research. Some calculations and interpolations have been necessary because of incomplete information. In formulation of diets, and for complete specifications for computer programming, it is necessary to use values for all involved nutrients. Accordingly, in the many instances where firm requirements cannot be stated on the basis of experimental data, the subcommittee has provided estimates of the requirements. These estimated values are indicated in *italics* to distinguish them from the established requirements shown in roman type.

The values reported, whether established or estimated, have not been increased by a margin of safety. The nutrient composition of feedstuffs is variable. Inadequate feed mixing, improper processing, and unfavorable storage conditions may reduce effective concentrations of dietary nutrients below those calculated to be present. A "margin of safety" should, accordingly, be added to the stated "requirements" in arriving at nutrient "allowances" to be used in feed formulations.

The feedstuffs used in poultry feeds contain diverse amounts of the various classes of nutrients. The classes of nutrients will be considered briefly in this section, and signs of deficiencies will be discussed in greater detail in the subsequent sections. The actual requirement values selected by the subcommittee for the individual nutrients are tabulated as indicated in the list of Tables (page vii). The values are expressed in percentages or in amounts per kilogram of feed. In some tables nutrient requirements per day also have been calculated. The latter values can be converted to units per unit weight of feed when accurate information on feed intake is available.

2 General Considerations Regarding the Provision of Nutrients and Water for Poultry

ENERGY

Terminology

The energy value of a feed ingredient or of a diet can be expressed in several ways. Energy terms for feedstuffs are defined and discussed in detail in *Nutritional Energetics of Domestic Animals and Glossary of Energy Terms* (second revised edition, 1981, National Academy Press). A brief description of the terms most frequently used in connection with poultry feeds appears below.

Calorie (cal) is the heat required to raise the temperature of 1 g of water from 16.5°C to 17.5°C. Since, however, the specific heat of water changes with temperature, a calorie is defined more precisely as 4.184 international joules.

Kilocalorie (kcal) is 1,000 calories and is the usual unit of energy used by the North American poultry feed industry.

Megacalorie (Mcal) is 1,000,000 calories and is commonly used as a basis for expressing requirements for other nutrients.

Gross Energy (E) is the energy released as heat when a substance is completely oxidized to carbon dioxide and water. It is also referred to as the heat of combustion. It is generally measured using 25 to 30 atmospheres of oxygen in a bomb calorimeter.

Apparent Digestible Energy (DE) is the gross energy of the feed consumed minus the gross energy of the feces. DE = (E of food per unit dry wt × dry wt of food) − (E of feces per unit dry wt × dry wt of feces). Birds excrete feces and urine via a cloaca, thus making it difficult to measure digestibility. As a consequence, DE values are not generally employed in poultry feed formulation.

Apparent Metabolizable Energy (ME) is the gross energy of the feed consumed minus the gross energy contained in the feces, urine, and gaseous products of digestion. For poultry the gaseous products are usually negligible so that ME represents the gross energy of the feed minus the gross energy of the excreta. A correction for nitrogen retained in the body is frequently applied to yield an ME_n value. ME_n is the most common measure of available energy in poultry nutrition.

True Metabolizable Energy (TME) for poultry is the gross energy of the feed minus the gross energy of the excreta of food origin. A correction for nitrogen retention may be applied to give a TME_n value. Most energy values in the literature have been determined by assays in which the test material is substituted for part of the test diet or for some ingredient of known ME value. When birds in these assays are fed ad libitum, the apparent ME values obtained approximate TME values for most feedstuffs, being only slightly lower.

Net Energy (NE) is metabolizable energy minus the energy lost as the heat increment. NE may include the energy used for maintenance only (NE_m) or for maintenance and production (NE_{m+p}). Since ME is used at different levels of efficiency for maintenance or the various productive functions, there is no absolute NE value for each feedstuff. For this reason productive energy, once a popular measure of the energy available to poultry from feedstuffs and an estimate of NE, has lost favor.

Procedures for Determination and Estimation

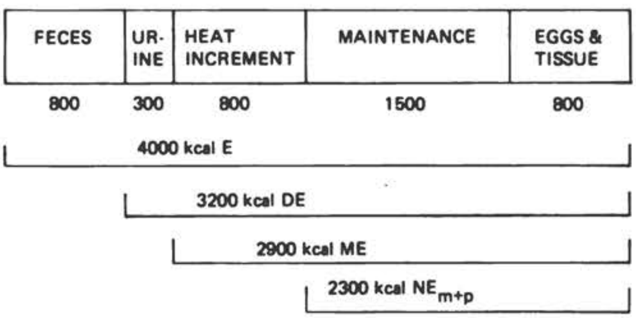
Much research has been carried out on techniques for both the actual determination of the utilizable energy contained in feedstuffs for poultry as well as on procedures for calculating energy values from chemical analyses.

Data from chemical analyses for moisture, crude protein, ether-extractable lipid, ash, crude fiber, and nitrogen-free extract may be used to give an approximation of the metabolizable energy contained in a feed. Some assumptions need to be made regarding the digestibility of the protein, lipid, and nitrogen-free extract components of the feed. If the digestibilities of the protein, fat, and nitrogen-free extract present are assumed to be 100 percent, multiplication of the dietary concentrations of the respective nutrients by 4.4, 8.7, and 4.0 kcal/g will provide an approximation of the ME concentration in kilocalories per kilogram of the diet. The value of 4.4 kcal/g of protein is based upon the excretion of uric acid as the end product of protein metabolism with a caloric value of 8.22 kcal/g of uric acid nitrogen. Subtracting 1.315 kcal (8.22 ÷ 6.25) from 5.7 kcal (the mean gross energy of protein) gives a value of 4.4 as an estimate of the metabolizable energy value of fully digestible protein.

Bioassay techniques for measurement of either the apparent or the true metabolizable energy values of a diet or of an individual feedstuff for poultry are reasonably straightforward.

Disposition of Dietary Energy

The diagram below illustrates the proportional relationships in the disposition of energy ingested as a layer diet. Energy is lost or utilized at various stages following consumption of the diet by the hen.



The values shown in the diagram indicate that, of 4,000 kcal contained in 1 kg of a particular diet, 2,900 kcal are capable of being metabolized by the hen and about 2,300 kcal are net energy available for maintenance and transfer into body tissue and egg. The relative amounts of both metabolizable and net energy will, of course, vary with the composition of the feedstuffs in the diet. Other factors, such as the species, genetic background, and age of poultry, as well as the environmental conditions, also influence the precise distribution of dietary energy into the various compartments. It should be noted that nearly all reported values for the metabolizable energy content of feedstuffs have been determined with young chicks. Data are particularly needed for chickens of different ages and for turkeys.

Requirements

Poultry tend to eat to satisfy their energy requirements if fed ad libitum. It is accordingly possible, within limits, to regulate the intake of all nutrients, except water, by including them in the diet in specific ratio to the amount of available energy in the diet. The importance of considering the energy content of the diet in order to promote the desired intake of all nutrients is therefore of obvious importance.

An absolute requirement for energy in terms of kilocalories per kilogram of diet (kcal/kg) cannot be stated because poultry adjust their feed intake to obtain their necessary daily requirement. Chickens fed low-energy diets of about 2,600 kcal/kg have been recorded as eating as much as 30 percent more than similar birds fed diets containing 3,200 kcal/kg. Thus, in comparison to high-energy diets, low to moderate energy levels allow birds to eat more and therefore to consume greater amounts of nutrients unless lesser concentrations of nutrients are used. If a higher concentration of energy is used in a diet, feed consumption will be reduced; dietary concentrations of nutrients should accordingly be increased in proportion to dietary energy in order to assure ingestion of the required amounts. Diets with higher concentrations of energy are usually more efficiently utilized in terms of unit amount of gain per unit amount of feed consumed. High-density, high-energy diets may result in consumption of excess energy because the decline in feed intake is not directly proportional to the increase in the energy density of the diet. The bulk (volume per unit weight) of a diet may also limit the quantity of nutrients that can be ingested per day. Pelleting of a bulky diet will increase the nutrient density per unit volume of diet and enable the consumption of more nutrients. The addition of fat to a diet increases the energy concentration and decreases the bulk density of the diet.

Food intake is controlled by certain areas of the brain that are believed to regulate the fill capacity of the crop as well as its emptying rate. There is also a relationship between feed content of the small intestine and the rate of crop emptying. Thus, gastrointestinal fill influences the areas of the brain controlling feed intake. Essential amino acids, likewise, influence feed intake either through their concentrations in blood coursing through the brain, where they influence other brain receptors, or by influencing the metabolism of amino acids in the liver. Deficiencies or excesses of certain essential amino acids cause feed intake to decline by influencing the areas of the brain controlling feed intake. Forced feeding of diets deficient in those amino acids will increase weight gain compared with that when chicks are fed the same diets ad libitum. There is considerable controversy over whether glucose levels in the blood of birds have any effect on regulating feed intake.

Environmental temperature has a marked influence on energy requirement and hence on feed intake. The warmer the environment, the lower the feed consumption. Feed consumption will decrease about 1.5 percent for each rise of 1°C above the thermoneutral zone. Conversely, colder temperatures cause increases in feed consumption. Diets marginal in a particular nutrient may perform better under colder environments because the birds eat more than at higher temperatures and thus consume a sufficient amount of the marginal nutrient. It follows, therefore, that the necessary concentrations of nutrients in a diet are related to the environmental temperature to which the birds eating the diet are exposed.

Other variable factors affecting dietary requirements for energy, in addition to those of nutritional balance, temperature, and the physical form of the feed, are stress, body size, feather coverage, and rate of growth or egg production. Poultry, through genetic inheritance and environmental circumstances, have a certain potential for performance. The level of dietary energy and the associated nutrient balance should facilitate expression of this potential. Under practical conditions economic considerations may place some limitation on the level of nutritional efficiency that is achieved.

Energy Values in Tables

In order to establish a base for the statement of the nutrient requirements of poultry, some assumptions must be made. It was assumed that the environmental temperatures to which poultry of various species and ages are exposed are ideal, or approach the optimum, for efficient growth and production. On this basis a practical dietary level of energy was then established for each species and age of poultry and nutrient requirements determined relative to a diet containing this amount of energy.

The ME values heading the lists of nutrient requirements in the tables should not be regarded as energy requirements. They were chosen as bases for the requirements of the other listed nutrients and represent dietary energy concentrations that are reasonable under practical conditions of feed formulation and poultry management.

PROTEIN AND AMINO ACIDS

Requirements

The dietary requirement for protein is actually a requirement for the amino acids contained in the protein. It is only in the form of the constituent amino acids that protein is absorbed from the intestine. Some of the amino acids are essential in that they have to be provided by the dietary protein or as dietary supplements. Some amino acids can be produced within the body of the bird by the transformation of other amino acids. Protein requirements therefore have two components, (1) the essential amino acids needed by the bird because it cannot synthesize them, or synthesize them rapidly enough, and (2) sufficient protein to supply either the nonessential amino acids themselves or to supply amino nitrogen for their synthesis. A statement of dietary protein concentration thus provides a convenient means of describing diets and serves as a basis for feed control regulations.

Factors affecting daily feed consumption were discussed in the Energy section. The influence of dietary energy on feed consumption is the major factor for consideration at moderate environmental temperatures. A somewhat low protein intake may, however, raise feed consumption. These relationships have stimulated interest in alternatives to dietary concentration as a way to express protein and amino acid requirements.

More research is needed in the general area of amino acid requirements. Currently stated requirements have no reference to environmental conditions. It may generally be assumed that the listed requirements are for a moderate climate (16–24°C). Percentage requirements should probably be raised or lowered respectively in warmer or colder environments in accordance with expected differences in feed or energy intakes. Such adjustments might aid in assuring the required daily intake of amino acids. The amino acid concentrations presented as requirements are intended to promote maximum growth and production. Maximum economic returns may not, however, always be consonant with maximum growth and production, particularly when protein prices are high. The dietary concentrations may, accordingly, be somewhat reduced, lowering growth rate to some degree, but maintaining economic return.

Amino acid requirements for layers are presented as percent of diet and on a daily intake basis. The latter provides a means of adjusting to varying feed intake, especially as modified by environmental temperature or dietary energy concentration. In order to make effective use of the daily amino acid intake concept, actual feed intake should be measured.

The productive state of the bird, i.e., rate of growth or egg production, determines amino acid requirements. The turkey poult and chicken broiler have high amino acid requirements per day to meet the requirements for rapid growth. The mature cockerel has a very low requirement compared to the laying hen, even though body size is actually greater and feed consumption is similar.

The genetic constitution of the bird determines body size, growth rate, and egg production. Nutrient requirements, therefore, differ among breeds and strains. Genetic differences in nutrient requirements may also occur because of differences in the efficiency of digestion, nutrient absorption, and metabolism of absorbed nutrients.

Dietary protein concentration can affect the requirements for individual essential amino acids. The balance among the essential amino acids, as well as the balance between the concentrations of essential and nonessential amino acids, should be maintained. The maintenance of these optimum balances is extremely important for the efficient utilization of dietary protein. It is desirable to meet the requirements for all the amino acids as closely as possible with avoidance of excesses of protein or of individual amino acids.

Specific Amino Acid Relationships

METHIONINE-CYSTINE

The requirement for methionine can be met only by methionine. The requirement for cystine can be met by cystine *or* methionine. Methionine readily undergoes metabolic conversion to cystine, whereas the reverse is not possible. If sulfate is deficient in the diet, a portion of the cystine that would normally be converted to sulfate may be spared by the addition of sulfates to the diet (e.g. sodium or potassium sulfate).

PHENYLALANINE-TYROSINE

The requirement for phenylalanine can be met only by phenylalanine. The requirement for tyrosine can be met by tyrosine *or* phenylalanine.

GLYCINE-SERINE

Glycine and serine can be used interchangeably in poultry diets. Usually when the overall protein requirement is met the amounts of glycine and/or serine are adequate.

ANTAGONISM AND IMBALANCE

The influence of protein on amino acid requirements may be due to interactions among specific amino acids or groups of amino acids. Some interactions, commonly referred to as antagonisms, occur among amino acids that are structurally related, e.g., leucine-isoleucine-valine and lysine-arginine. Increasing the dietary level of one or two of a group may increase the requirement for another from the same group. Other interactions, referred to as imbalances, occur when diets are supplemented with the second-limiting amino acid, or all essential amino acids except the limiting amino acid. In some instances (e.g., threonine imbalance), several amino acids, individually or as groups, also may cause increased need for the limiting amino acid. Antagonisms appear to have a metabolic basis in which the amino acid(s) present in excess interfere with the retention of the other amino acid(s) of the group. Imbalances cause the blood level of the limiting amino acid to decrease without affecting its overall retention. This results in reduced food intake, the major cause of reduced performance. In supplementing diets with limiting amino acids, it is important to supplement first with the most-limiting one, followed by the second-most-limiting one. Inadvertent oversupplementation with only the second-most-limiting amino acid may create an imbalance and accentuate the primary deficiency.

CONVERSION OF AMINO ACIDS TO VITAMINS

Methionine may partly compensate for deficiencies of choline or vitamin B_{12} by providing needed methyl groups. Tryptophan may alleviate a niacin deficiency through metabolic conversion to niacin. Reliance on these conversions is, however, unwise, both nutritionally and economically.

AMINO ACID AVAILABILITY

When diets are formulated on the basis of feed analysis data, the assumption is generally made that amino acids are 80-90 percent available from the feedstuff protein. This assumption is not necessarily valid. Native proteins vary markedly in their digestibility. Processing of feedstuffs may improve digestibility. For example, the digestibility of feather protein (keratin) is improved during the manufacture of feather meal. Heat treatment of soybean meal inactivates compounds that interfere with trypsin digestion of protein in the intestine, thereby improving the availability of amino acids to the bird. Processing may, if not carried out with careful control, reduce digestibility of the product. Overheating during the drying of bloodmeal, meat scrap, and fish or fishwaste can seriously lower digestibility and the availability of specific amino acids (of which lysine is probably the most critical under practical conditions of feed formulation).

FATS

Fats are important ingredients in poultry diets, and, although used primarily to supply energy, fats also improve the physical consistency of diets and dispersion of microingredients in feed mixtures. Fats used for feeding poultry are of three general sources: animal or poultry fats obtained from the rendering industry, restaurant greases, acidulated soapstocks from the vegetable oil industry, and/or mixtures thereof. Definitions of these fats are presented in the Official Publication of the Association of American Feed Control Officials (AAFCO) available from the Department of Agriculture, Charleston, WV 25305. Quality characteristics of fats that may affect their nutritional value or safety of use are important. Characteristics of fats used to assess nutritional values include moisture, impurities, unsaponifiables, free fatty acids, total fatty acids, and fatty acid composition. Fats for poultry feed should be stabilized against oxidation. Concentrations of undesirable residues (e.g., chlorinated hydrocarbons) in fats used in poultry feeds must not exceed the limits established by state and federal agencies.

The fatty acid composition and ME values, or ranges in ME values, for different supplemental fats are presented in Table 27. Some uncertainty exists, however, about the true contribution of certain fats to the ME of poultry diets. Fatty acid composition of the fat, free fatty acid content of the fat, level of fat inclusion in the diet, ingredient composition of the diet, and age of poultry may influence the ME contribution of fats. Thus, ranges are presented in Table 27 for the ME values of fats used frequently in poultry feeds. Generally, ME values at the lower portion of the ranges should be used for poultry less than 3 or 4 weeks of age. Values in the upper part of the ranges would be appropriate for adult poultry.

Fats often increase the utilization of dietary energy by poultry in excess of the increase expected when the ME of the fat is added to the ME values of the other dietary constituents. Supplemental fats may increase energy utilization in adult chickens in association with a decreased rate of food passage through the gastrointestinal tract. Furthermore, because the heat increment of feeding of fats is less per unit weight than that of carbohydrates, the substitution of fat for a portion of the dietary carbohydrates may enhance energy utilization by reducing the heat increment of feeding.

The fatty acid composition of body fat and egg fat may be altered by dietary fats. This is especially true when substantial levels of unsaturated fats such as corn oil or sunflower oil are used. In these instances, the fatty acid composition of body fat and/or egg fat tends to reflect that of the dietary unsaturated fat. Feeding saturated fats following the feeding of unsaturated fats will cause the body or egg fat to become more saturated.

MINERALS

Minerals are required for the formation of the skeleton, as components of various compounds with particular functions within the body, as activators of enzymes, and for the maintenance of necessary osmotic relationships within the body of the bird. Calcium and phosphorus are essential for the formation and maintenance of the skeletal structure. Sodium, potassium, magnesium, and chloride function with phosphates and bicarbonate to maintain homeostasis of osmotic relationships and pH throughout the body. Most of the calcium in the diet of the growing bird is used for bone formation, whereas in the mature laying fowl most dietary calcium is used for egg shell formation. Other functions of calcium include roles in blood clotting and neuromuscular function. An excess of dietary calcium interferes with availability of other minerals such as magnesium, manganese, and zinc. High concentrations of calcium carbonate (limestone) and calcium phosphates in the diet may make the diet unpalatable. The calcium requirement of the laying hen is difficult to define. The listed requirement of 3.4 percent is believed to represent the mean dietary concentration for the quantities of feed likely to be consumed (110 grams per hen per day) over a considerable range of environmental temperature. The biological availability of calcium is high from most commonly used supplements.

Phosphorus, in addition to its function in bone formation, is also required in the metabolism of carbohydrates and fats and is a component of all living cells. It is important that sufficient phosphorus be provided in available form. Only 30 to 40 percent of the phosphorus in plant products is nonphytin phosphorus and considered to be available to poultry. There is disagreement concerning the ability of poultry to utilize phytin phosphorus. Most data, however, indicate that the utilization of phytin phosphorus, by young or adult poultry, is negligible if dietary calcium concentrations are sufficient to meet the birds' requirements. There may be breed differences in this regard. Commonly used inorganic phosphorus supplements are listed in Table 29. The biological availability of the phosphorus in these supplements may vary.

Sodium and chloride are essential for all animals. Dietary concentrations of salt generally employed are those that will just support maximum growth rate or egg production. Higher concentrations lead to excessive consumption of water and attendant problems with ventilation and wet droppings.

Dietary proportions of sodium, potassium, and chlorine are important determinants of acid-base balance. The appropriate balance of these electrolytes is based on sodium and potassium versus chlorine, where each element is expressed in milliequivalents per kilogram of diet. Experiments show that sodium and potassium are alkalogenic (have an alkaline-producing effect), whereas chlorine is acidogenic (has an acid-producing effect). Chloride tends to decrease blood pH and bicarbonate concentration, whereas sodium and potassium tend to increase blood pH and bicarbonate concentration. The proper dietary balance of sodium, potassium, and chlorine is necessary for growth, bone development, egg shell quality, and amino acid utilization.

Some mineral elements are required in very small amounts. The requirements are often met from concentrations naturally present in feeds. Soils vary, however, in their content of trace minerals. As a consequence, feedstuffs grown in some geographic areas may be marginal or deficient in some elements. Thus, poultry diets may require supplementation to ensure adequate intake of trace minerals. Interactions occur between various minerals (e.g., copper and molybdenum, selenium and mercury, calcium and zinc, or calcium and manganese). Excessive concentrations of an element may result in a deficiency in the amount available to the bird of some other element. Dietary supplementation with trace elements should be undertaken with great care and consideration for the possible interactions. Mineral salts used as feed supplements are not usually pure compounds but contain variable amounts of other minerals. Examples of the variety of minerals that may be present in feed-grade mineral supplements are shown in Table 29.

Experimental diets may sometimes be formulated from purified or chemically defined ingredients. When this is done additions of the trace minerals listed in Table 1 may be desirable. Several of these mineral elements have been demonstrated to be essential under the special conditions of purified diets and controlled environments in which the water supplied is deionized and the air is filtered. Requirements have not been established for these elements; the dietary concentrations listed in Table 1 are only guidelines.

TABLE 1 Suggested Trace Mineral Supplements to Chemically Defined Diets

Element	mg/kg of Diet
Boron	2
Chromium	3
Molybdenum	1
Nickel	0.1
Silicon	250
Tin	3
Vanadium	0.2
Fluorine	20
Inorganic sulfate	[a]

[a]Sulfur is supplied to the diet by methionine and cystine. There may be a response to inorganic sulfate if the diet is low in cystine.

VITAMINS

Vitamins are generally classified under two headings: fat-soluble vitamins A, D, E, and K and water-soluble vitamins, which include the so-called B-complex vitamins and vitamin C (ascorbic acid). Vitamin C is synthesized by poultry and is, accordingly, not considered a required dietary nutrient. There is some evidence, nevertheless, of a favorable response to vitamin C by birds under stress.

The requirements for most vitamins are given in terms of milligrams per kilogram of diet. Exceptions are vitamins A, D, and E, for which the requirements are commonly stated in units. Units are used to express the requirements for these vitamins because different forms of the vitamins have different biological activities.

Requirements for vitamin A are expressed in either International Units (IU) or U.S. Pharmacopeia units (USP) per kilogram of diet. The international standards for vitamin A activity are as follows:

> 1 IU of vitamin A = 1 USP unit = vitamin A activity of 0.3 μg crystalline vitamin A alcohol (retinol) or 0.344 μg vitamin A acetate or 0.55 μg vitamin A palmitate. One IU of vitamin A activity is equivalent to the activity of 0.6 μg of β-carotene; expressed otherwise 1 mg β-carotene = 1,667 IU vitamin A (for poultry).

Requirements of poultry for vitamin D are expressed in International Chick Units (ICU), which are based on the activity of vitamin D_3 in chick bioassays. Birds effectively use vitamin D_3 from fish oils and irradiated animal sterol. They do not, however, use vitamin D_2 from irradiated plant sterol as effectively as do rats and other mammals. One ICU of vitamin D is defined as the vitamin D activity for the chick of 0.025 μg of vitamin D_3 (cholecalciferol). The potency of an unknown sample, if it is to be expressed in ICU, must be measured with chicks rather than with rats because of the difference in response of the two species to vitamin D_2. The listed requirements for vitamin D are based on diets containing the stated requirements for calcium and available phosphorus.

One IU of vitamin E is the activity of 1 mg of synthetic DL-α-tocopheryl acetate or 0.735 mg D-α-tocopheryl acetate or 0.671 mg D-α-tocopherol or 0.909 mg DL-α-tocopherol. The dietary requirement for vitamin E is highly variable and depends upon the concentration and type of fat in the diet, the concentration of selenium, and the presence of antioxidants.

Vitamin K activity is exhibited by a number of naturally occurring and synthetic compounds with varying solubilities in fat and water. Menadione (2-methyl-1,4-naphthoquinone) is a fat-soluble, synthetic compound that can be considered as the reference standard for vitamin K activity. Two naturally occurring forms are K_1 or phylloquinone (2-methyl-3 phytyl-1,4-naphthoquinone) and K_2 or menaquinone (K_1 substituted with two to seven isoprene units). Water-soluble forms include menadione sodium bisulfite (MSB), menadione sodium bisulfite complex (MSBC), and menadione dimethylpyrimidol (MPB). The theoretical activity of these compounds can be calculated on the basis of the proportion of menadione present in the molecule.

Requirements for some of the vitamins may be met by the amounts occurring as natural components of the customary feedstuffs used in compounding diets. When the conventional feedstuffs are not available, however, the products used in substitution may not supply sufficient amounts of the various vitamins. Formulators of poultry feeds should therefore be alert to the need for dietary supplementation with vitamins usually assumed to be supplied by the feedstuffs.

The requirements for the water-soluble vitamins are interrelated in some instances. They are also dependent upon the nature of the diet. The type of carbohydrate, protein concentration, and amino acid balance are major factors determining the dietary requirements for several vitamins.

TABLE 2 Daily Water Consumption[a] by Chickens and Turkeys of Different Ages

	per 1,000 Birds					
	Chicken Broilers[b]		Leghorn-Type Pullets		Turkeys[b]	
Age (week)	Liters	Gallons (U.S.)	Liters	Gallons (U.S.)	Liters	Gallons (U.S.)
1	20	5	19	5	38	10
2	50	13	38	10	76	20
3	90	24	45	12	114	30
4	140	37	64	17	151	40
5	200	53	83	22	189	50
6	260	69	95	25	227	60
7	320	85	106	28	284	75
8	380	100	114	30	360	95
9			132	35	435	115
10			144	38	473	125
12			151	40	568	150
15			158	42	606	160
20			170	45	757	200
			Laying or Breeding			
35			189	50	M 908	240
					F 492	130

[a]Will vary considerably depending on temperature and diet composition.
[b]Mixed sexes.

WATER

Water must be regarded as an essential nutrient, although it is not possible to state precise requirements. The amount needed will depend upon environmental temperature and relative humidity, the composition of the diet, rate of egg production, and efficiency of kidney resorption of water in individual birds. Generally birds drink approximately twice as much water as the amount of feed consumed on a weight basis.

The figures given for water consumption in Table 2 are for temperatures of about 21°C except for brooding chicks and poults. With broilers, consumption will increase about 7 percent for each 1°C above 21°C. Laying hens may consume from 40 to 80 gal (150 to 300 liters)/day/1,000 birds, depending upon temperature. Survival under extremely hot conditions is influenced by the ability to consume large quantities of water, or more precisely, the ability to lose water from the respiratory surfaces of the body. This ability varies from strain to strain.

Water restoration, after extended periods (36 to 40 hours) of water deprivation, may cause a "drunken syndrome" or "water intoxication," leading to death, in young turkeys.

The salt content and pH of water may influence the use of the drinking water as an administration route for vitamins and drugs. Turkeys are known to detect very minor differences in the flavor of medicated water and may accept drugs in one water supply but not in another.

Intermittent provision of water is sometimes used to reduce the water content of the droppings and to control feed intake in laying hens. Because birds differ in their ability to conserve body water by increasing kidney resorption, there is a danger of causing dehydration of some birds by practicing water restriction of a flock.

Some water supplies contain considerable concentrations of sulfur or sulfates, nitrates, and various trace minerals. These are usually readily absorbed from the intestine and may be either useful or harmful to the bird.

The National Research Council (1974) suggests the following guidelines for the suitability for poultry of water with different concentrations of total dissolved solids (TDS).

TDS (ppm)	Comments
Less than 1,000	These waters should present no serious burden to any class of poultry.
1,000–2,999	These waters should be satisfactory for all classes of poultry. They may cause watery droppings (especially at the higher levels) but should not affect health or performance.
3,000–4,999	These are poor waters for poultry, often causing watery droppings, increased mortality, and decreased growth (especially in turkeys).
5,000–6,999	These are not acceptable waters for poultry and almost always cause some type of problem, especially at the upper limits, where reduced growth and production or increased mortality probably will occur.
7,000–10,000	These waters are unfit for poultry but may be suitable for other livestock.
Over 10,000	Should not be used for any livestock or poultry.

XANTHOPHYLL

Xanthophylls constitute a group of naturally occurring oxycarotenoid pigments that are responsible for the yellow coloration in egg yolks, the shanks and feet of birds, and the yellow in the fat and skin of poultry. Although the various xanthophyll pigments occur widely in natural plant products, only a few of the natural products used in poultry feeds contain quantities sufficient to affect egg yolk and carcass color. Alfalfa meal, yellow corn, and corn gluten meal are the major sources of xanthophyll pigments in poultry diets.

The term xanthophyll is a generic term frequently applied to the entire group of oxycarotenoids. Individual xanthophylls differ, however, in their ability to impart color. Alfalfa meal contains several types, but the one of greatest abundance and importance is lutein, which tends to impart a yellow color, while corn and corn gluten meal contain primarily zeaxanthin, which tends to impart an orange-red color.

Xanthophylls are unstable and may deteriorate as a result of oxidation during the storage of feedstuffs. The addition of antioxidant offers some protection against storage losses.

The total xanthophyll concentrations found in a few feedstuffs that are rich in these pigments are listed in Table 3. The xanthophylls in algae and marigold petals promote a different shade of color than those in corn and alfalfa. The absorption of xanthophylls from the feed is reduced when birds suffer from coccidiosis and certain other diseases. As a result, reduction in the coloration of shanks and skin is often associated with these diseases.

UNIDENTIFIED FACTORS

There are numerous reports of favorable responses to the dietary inclusion of natural products that have not been identified with any of the known nutrients. Stimulation of growth, increased egg production and hatchability, reduced liver fat, improved product quality, and reduced toxicity of minerals have been stated as evidence for the presence of unidentified factors in diverse products such as egg yolk, whey, yeast, fish and meat by-products, soybeans, corn, green forages, and fermentation by-products. Some responses, originally attributed to unidentified factors, have subsequently been shown to be the result of trace minerals. The complexity of optimum dietary balance among the minerals, and the evidence for the essentiality of some of the "newer" trace elements, suggest that components of natural products may, directly or indirectly, be factors associated with the mineral nutrition of poultry.

ANTIBIOTICS

Some antibiotics, although not nutrients in the sense that they are required by poultry, stimulate growth and improve efficiency of feed conversion under most conditions when added to the diet at low concentrations (usually 1 to 10 mg/kg of diet and sometimes as high as 50 mg

TABLE 3 Xanthophyll-Rich Feedstuffs

Feedstuffs	Xanthophylls (mg/kg)
Alfalfa meal, 17% protein	260
Alfalfa meal, 20% protein	280
Alfalfa meal, 22% protein	330
Alfalfa juice protein, 40% protein	800
Algae, common, dried	2,000
Corn, yellow	17
Corn gluten meal, 41% protein	175
Corn gluten meal, 60% protein	290
Marigold petal meal	7,000

for young birds, depending on the antibiotic). They are, accordingly, classified as additives and as growth promotants. Egg production is also frequently improved by dietary supplementation with antibiotics. It is not clearly understood why antibiotics stimulate growth and under what conditions they may do so. Since antibiotics do not stimulate growth under germ-free conditions, it is likely that stimulus to growth results from either suppression of microorganisms with adverse effects or encouragement of others with desirable effects. The intestinal wall is known to be thinner when antibiotics are fed to chicks.

There is some concern that feeding of low concentrations of antibiotics may favor proliferation of antibiotic-resistant microorganisms with serious consequences when antibiotics are required for disease control in either man or domestic animals. There is, however, no evidence that low-level antibiotic feeding constitutes a public health hazard (National Research Council, 1980). Constraints on the use of particular antibiotics permitted for use in poultry feeds vary among countries and are subject to change.

Detailed information on specific antimicrobial agents, levels of usage, and legal requirements for use may be found in the Feed Additive Compendium published each year by the Miller Publishing Company, 2501 Wayzata Boulevard, Minneapolis, MN 55440, and in the compendium of Medicating Ingredient Brochures, Plant Products Division, Canada Department of Agriculture, Ottawa, Canada.

For official information concerning Food and Drug Administration approval of antibiotics and other animal drugs, the *Code of Federal Regulations (CFR), Title 21*, should be consulted. *Title 21* is revised at least once each year as of April 1. The *CFR* is kept up to date by the individual issues of the *Federal Register*. These two publications must be used together to determine the latest version of any given rule. *Title 21* is published in six parts: Part 500–599 covers animal drugs, feeds, and related products and is for sale by the Superintendent of Documents, U.S. Government Printing Office, Washington, DC 20402, for $13.00 (1984 price). The *Federal Register* is available from the Superintendent of Documents for $300.00/year, which includes monthly issues of the "List of CFR Sections Affected" and "The Federal Register Index."

3 Nutrient Requirements of Chickens

Chickens vary greatly according to the purpose for which they have been developed. Those intended for the production of eggs for human consumption (Leghorn-type) have a small body size and are prolific layers, whereas those used as broilers or broiler-breeders have rapid growth rates, large body size, and are less efficient egg layers. Methods of feeding differ for the two kinds of chickens.

Leghorn-type chickens are generally fed ad libitum during the growing and laying periods. Broilers also are fed ad libitum to ensure rapid development to market size. Broiler-breeders, however, are maintained for hatching egg production. Since they tend to become obese, feed intake is usually restricted. Feeding schedules that allow the desired levels of restriction are available for broiler-breeders of different genetic stocks. Low-protein and/or amino-acid-imbalanced diets fed ad libitum will also retard pullet growth and development.

Restricted feeding of Leghorn-type pullets is seldom practiced during the growing period because restriction of lighting effectively controls feed consumption and sexual development. Feeding programs for Leghorn-type pullets and hens may be modified after maximum rate of egg production has been attained. Occasionally, laying hens will consume excess feed during the latter phases of egg production with resultant obesity. Feed efficiency is reduced and the incidence of fatty liver syndrome is increased under these conditions. Limiting feed intake to 90 to 95 percent of full feed consumption seems desirable when overconsumption of energy is a problem. Data on feed consumption in individual flocks, together with information on body weight, ambient temperature, and rate of egg production, may be used to determine the desired degree of feed restriction.

There has been a trend to "phase-feed" laying hens to adjust nutrient intake in accordance with the changing nutritional needs of hens as the rate of egg production declines during the laying year. Although phase feeding has been used with apparent success commercially, there is insufficient experimental data to serve as a basis for phase-feeding recommendations in this publication.

After 8 to 12 months of egg production, some flocks of hens are molted as a means of recycling hens for another period of production. A combination of feed and light restriction is used to stop egg production and induce molt. The hens are "rested" for up to 4 to 6 weeks. Upon refeeding, and increasing the hours of light, the birds are stimulated to resume egg production.

Nutrient requirements of Leghorn-type laying hens are expressed in Table 4 in terms of dietary concentration and on a daily intake basis. Because hens eat primarily to satisfy their energy needs, it is important to relate dietary metabolizable energy concentrations to energy requirements. Energy requirements of hens at different ambient temperatures may vary substantially. Absolute requirements for protein, amino acids, vitamins, and minerals are, on the other hand, little affected by temperature.

TABLE 4 Nutrient Requirements of Leghorn-Type Chickens as Percentages or as Milligrams or Units Per Kilogram of Diet

		Growing			Laying		Breeding
Energy Base		0–6 Weeks	6–14 Weeks	14–20 Weeks		Daily Intake	
kcal ME/kg Diet[a] →		2,900	2,900	2,900	2,900	per Hen (mg)[b]	2,900
Protein	%	18	15	12	14.5	16,000	14.5
Arginine	%	1.00	0.83	0.67	0.68	750	0.68
Glycine and Serine	%	0.70	0.58	0.47	*0.50*	550	*0.50*
Histidine	%	0.26	0.22	0.17	*0.16*	180	*0.16*
Isoleucine	%	0.60	0.50	0.40	0.50	550	0.50
Leucine	%	1.00	0.83	0.67	0.73	800	0.73
Lysine	%	0.85	0.60	0.45	0.64	700	0.64
Methionine + cystine	%	0.60	0.50	0.40	0.55	600	0.55
Methionine	%	0.30	0.25	0.20	0.32	350	0.32
Phenylalanine + tyrosine	%	1.00	0.83	0.67	*0.80*	880	*0.80*
Phenylalanine	%	0.54	0.45	0.36	*0.40*	440	*0.40*
Threonine	%	0.68	0.57	0.37	0.45	500	0.45
Tryptophan	%	0.17	0.14	0.11	0.14	150	0.14
Valine	%	0.62	0.52	0.41	*0.55*	600	*0.55*
Linoleic acid	%	1.00	*1.00*	*1.00*	1.00	1,100	1.00
Calcium	%	0.80	0.70	0.60	*3.40*	3,750	*3.40*
Phosphorus, available	%	0.40	0.35	0.30	0.32	350	0.32
Potassium	%	0.40	*0.30*	*0.25*	0.15	165	0.15
Sodium	%	0.15	0.15	0.15	0.15	165	0.15
Chlorine	%	0.15	*0.12*	*0.12*	0.15	165	0.15
Magnesium	mg	600	*500*	*400*	500	55	500
Manganese	mg	60	*30*	*30*	*30*	3.30	*60*
Zinc	mg	40	*35*	*35*	*50*	5.50	*65*
Iron	mg	80	*60*	*60*	*50*	5.50	*60*
Copper	mg	8	*6*	*6*	*6*	0.88	*8*
Iodine	mg	0.35	*0.35*	*0.35*	0.30	0.03	0.30
Selenium	mg	0.15	*0.10*	*0.10*	0.10	0.01	0.10
Vitamin A	IU	1,500	1,500	1,500	4,000	440	4,000
Vitamin D	ICU	200	200	200	500	55	500
Vitamin E	IU	10	*5*	*5*	*5*	0.55	*10*
Vitamin K	mg	0.50	*0.50*	*0.50*	*0.50*	0.055	*0.50*
Riboflavin	mg	3.60	1.80	1.80	2.20	0.242	3.80
Pantothenic acid	mg	10.0	10.0	10.0	2.20	0.242	10.0
Niacin	mg	27.0	11.0	11.0	*10.0*	1.10	*10.0*
Vitamin B_{12}	mg	0.009	0.003	0.003	0.004	0.00044	0.004
Choline	mg	1,300	900	500	?	?	?
Biotin	mg	0.15	*0.10*	*0.10*	*0.10*	0.011	0.15
Folacin	mg	0.55	*0.25*	*0.25*	0.25	0.0275	0.35
Thiamin	mg	1.8	*1.3*	*1.3*	*0.80*	0.088	*0.80*
Pyridoxine	mg	3.0	*3.0*	*3.0*	*3.0*	0.33	*4.50*

[a] These are typical dietary energy concentrations.
[b] Assumes an average daily intake of 110 g of feed/hen daily.

TABLE 5 Body Weights and Feed Requirements of Leghorn-Type Pullets and Hens

Age (weeks)	Body Weight[a] (g)	Feed Consumption[b] (g/week)	Typical Egg Production (hen-day %)
0	35	45	—
2	135	90	—
4	270	180	—
6	450	260	—
8	620	325	—
10	790	385	—
12	950	430	—
14	1,060	460	—
16	1,160	460	—
18	1,260	460	—
20	1,360	460	—
22	1,425	525	10
24	1,500	595	38
26	1,575	665	64
30	1,725	770	88
40	1,815	770	80
50	1,870	765	74
60	1,900	755	68
70	1,900	740	62

[a]Pullets and hens of Leghorn-type strains are generally fed ad libitum but are occasionally control-fed to limit body weights. Values shown are typical but will vary with strain differences, season, and lighting. Specific breeder guidelines should be consulted for desired schedules of weights and feed consumption.

[b]Based on diets containing 2,900 ME kcal/kg. Consumption will vary depending upon the caloric density of the diet, environmental temperature, and rate of production (see Table 9).

TABLE 6 Nutrient Requirements of Broilers as Percentages or as Milligrams or Units Per Kilogram of Diet

Energy Base kcal ME/kg Diet[a]	→	Weeks 0–3 3,200	Weeks 3–6 3,200	Weeks 6–8 3,200
Protein	%	23.0	20.0	18.0
Arginine	%	1.44	1.20	1.00
Glycine + Serine	%	1.50	1.00	0.70
Histidine	%	0.35	0.30	0.26
Isoleucine	%	0.80	0.70	0.60
Leucine	%	1.35	1.18	1.00
Lysine	%	1.20	1.00	0.85
Methionine + Cystine	%	0.93	0.72	0.60
Methionine	%	0.50	0.38	0.32
Phenylalanine + Tyrosine	%	1.34	1.17	1.00
Phenylalanine	%	0.72	0.63	0.54
Threonine	%	0.80	0.74	0.68
Tryptophan	%	0.23	0.18	0.17
Valine	%	0.82	0.72	0.62
Linoleic acid	%	1.00	1.00	1.00
Calcium	%	1.00	0.90	0.80
Phosphorus, available	%	0.45	0.40	0.35
Potassium	%	0.40	0.35	0.30
Sodium	%	0.15	0.15	0.15
Chlorine	%	0.15	0.15	0.15
Magnesium	mg	600	600	600
Manganese	mg	60.0	60.0	60.0
Zinc	mg	40.0	40.0	40.0
Iron	mg	80.0	80.0	80.0
Copper	mg	8.0	8.0	8.0
Iodine	mg	0.35	0.35	0.35
Selenium	mg	0.15	0.15	0.15
Vitamin A	IU	1,500	1,500	1,500
Vitamin D	ICU	200	200	200
Vitamin E	IU	10	10	10
Vitamin K	mg	0.50	*0.50*	*0.50*
Riboflavin	mg	3.60	3.60	3.60
Pantothenic acid	mg	10.0	10.0	10.0
Niacin	mg	27.0	27.0	11.0
Vitamin B_{12}	mg	0.009	0.009	0.003
Choline	mg	1,300	*850*	*500*
Biotin	mg	0.15	0.15	*0.10*
Folacin	mg	0.55	0.55	*0.25*
Thiamin	mg	1.80	1.80	1.80
Pyridoxine	mg	3.0	3.0	2.5

[a]These are typical dietary energy concentrations.

TABLE 7 Body Weights and Feed Requirements of Broilers[a]

Age (weeks)	Body Weights (g)		Weekly Feed Consumption (g)		Cumulative Feed Consumption (g)		Weekly Energy Consumption (ME kcal/bird)		Cumulative Energy Consumption (ME kcal/bird)	
	M	F	M	F	M	F	M	F	M	F
1	130	120	120	110	120	110	385	350	385	350
2	320	300	260	240	380	350	830	770	1,215	1,120
3	560	515	390	355	770	705	1,250	1,135	2,465	2,255
4	860	790	535	500	1,305	1,205	1,710	1,600	4,175	3,855
5	1,250	1,110	740	645	2,045	1,850	2,370	2,065	6,545	5,920
6	1,690	1,430	980	800	3,025	2,650	3,135	2,560	9,680	8,480
7	2,100	1,745	1,095	910	4,120	3,560	3,505	2,910	13,185	11,390
8	2,520	2,060	1,210	970	5,330	4,530	3,870	3,105	17,055	14,495
9	2,925	2,350	1,320	1,010	6,650	5,540	4,225	3,230	21,280	17,725

[a]Typical for broilers fed well-balanced diets containing 3,200 ME kcal/kg.

TABLE 8 Nutrient Requirements of Meat-Type Hens for Breeding Purposes[a]

Energy Base kcal ME/kg Diet →		2,850[b]	Daily Intake Per Hen (mg)
Protein	%	14.5	22,000
Arginine	%	0.74	1,110
Glycine + serine	%	0.62	932
Histidine	%	0.14	205
Isoleucine	%	0.57	850
Leucine	%	0.83	1,250
Lysine	%	0.51	765
Methionine + cystine	%	0.55	820
Methionine	%	0.35	520
Phenylalanine + tyrosine	%	0.75	1,112
Phenylalanine	%	0.41	610
Threonine	%	0.48	720
Tryptophan	%	0.13	190
Valine	%	0.63	950
Calcium	%	2.75	4,125
Phosphorus, available	%	0.25	375
Sodium	%	0.10	150

[a]Diets are generally fed on a limited intake basis to control body weight gains. Adjust quantity of feed offered based on desired body weights and egg production levels for specific breed or strain.

[b]Diets for laying hens generally are fed to provide daily energy intakes of 375 to 450 ME kcal/day based on body weight, environmental temperature, and rate of egg production. Percentage of nutrients shown is typical of hens given 425 ME kcal/day.

TABLE 9 Typical Body Weights and Feed Allowances for Male and Female Meat-Type Chickens (Replacement Stock)[a]

Age (weeks)	Male Body Weight[b] (g)	Male Feed Consumption[c] (g/week)	Female Body Weight[b] (g)	Female Feed Consumption[c] (g/week)	Typical Egg Production (hen-day %)
0	40	100	40	75	—
2	250	250	225	225	—
4	545	350–385	455	315–330	—
6	795	390–425	660	330–350	—
8	1,020	405–475	840	350–400	—
10	1,250	475–550	1,000	385–445	—
12	1,480	540–625	1,180	425–480	—
14	1,700	575–700	1,360	460–550	—
16	1,930	625–765	1,550	495–600	—
18	2,150	665–825	1,730	525–670	—
20	2,400	—[d]	1,930	570–730	—
22	2,640	—	2,110	635–795	10
24	3,200	—	2,450	800–925	15
26	3,540	—	2,730	950–1,050	30
28	3,750	—	2,880	1,078–1,141	56
30	3,900	—	3,000	1,078–1,141	75
32	4,090	—	3,090	1,078–1,141	80
34	4,220	—	3,130	1,078–1,141	78
36	4,340	—	3,160	1,078–1,141	76
38	4,450	—	3,180	1,071–1,134	73
40	4,540	—	3,180	1,064–1,127	72

[a]Broiler-breeder strains must be grown on a controlled feeding program to limit weight. Values shown are typical but will vary according to strain. Specific breeder guidelines should be consulted for desired schedule of weights and feed allotments.

[b]Values are typical for fall-hatched chicks. Spring-hatched chicks will have decreasing natural daylight during the time of sexual maturity and usually need to be heavier to attain sexual maturity at the desired age.

[c]Adjust as required to maintain desired body weight.

[d]Males and females intermingled.

TABLE 10 Metabolizable Energy Required Daily by Chickens in Relation to Body Weight and Egg Production[a]

Body Weight (kg)	Rate of Egg Production (%) 0	50	60	70	80	90
	Metabolizable Energy/Hen Daily (kcal)[b]					
1.0	130	192	205	217	229	242
1.5	177	239	251	264	276	289
2.0	218	280	292	305	317	330
2.5	259	321	333	346	358	371
3.0	296	358	370	383	395	408
3.5	333	395	408	420	432	445

[a]A number of formulas have been suggested for prediction of the daily energy requirements of chickens. The formula used here was derived from that in *Effect of Environment on Nutrient Requirements of Domestic Animals* (NRC, 1981).

$$\text{ME/hen daily} = W^{0.75}(173 - 1.95T) + 5.5\Delta W + 2.07EE$$

where: W = body weight (kg),
T = ambient temperature (°C),
ΔW = change in body weight in g/day, and
EE = daily egg mass (g).

[b]Temperature of 22°, egg weight of 60 g, and no change in body weight were used in calculations.

4 Nutrient Requirements of Turkeys

There are two distinct areas of emphasis in the feeding of turkeys. The more common is feeding for market turkey production. Of great importance, however, is the feeding of breeder stock.

For market turkey production most turkeys are of the large type. The usual marketing age of male (tom) turkeys is 19 to 25 weeks at live weights of 10.5 to 16 kg. Those of the younger age are often sold as oven-ready dressed birds; those of the older age are generally used either for further processing or for the restaurant trade. Female (hen) turkeys are frequently marketed at 16 to 17 weeks of age at live weights of about 6.5 kg. Medium and small turkeys (roaster-fryers) are often sold at younger ages and lighter live weights. Usual live body weights for these birds are about 4.5 kg.

The formulations of the diets fed to market turkeys are modified as the birds grow. The nutrient requirements shown in Table 11 reflect those changes as made at 4- or 3-week intervals. In practice the changes may occur more or less frequently than indicated here. Nutritional adjustments are often made for expected ambient temperature variations in order to assure that the birds consume the necessary amount of protein, vitamins, and minerals, regardless of changes in feed consumption.

Feeding programs for breeder stock are usually divided into prebreeding and breeding periods. The prebreeding or holding diets may be fed when the breeder stock is selected at about 16 weeks of age. Females are fed the holding diet until the time of light stimulation, often at 30 weeks of age. Thereafter breeder diets are fed. In the case of males, light stimulation is normally initiated at about 26 weeks of age. A nutritionally balanced holding diet may be fed from the time of breeder selection throughout the breeding season. In some programs, the male turkeys' body weights are controlled by limited feeding of the diet.

It is not necessary to feed low-energy diets or to restrict feed intake for hen turkeys in the prebreeding period. Corn-soybean meal type diets may be fed ad libitum. Growth restriction does not result in any consistent improvement in reproductive performance and may actually be detrimental under some conditions. The use of "holding feeds" for potential turkey breeders is, however, common practice. These feeds are usually designed with medium energy concentrations to stabilize development and weight gains after mature body weight is attained. Care should be taken to maintain adequate intake of vitamins and minerals during the holding period so that the breeders are not depleted of these nutrients prior to the onset of lay.

TABLE 11 Nutrient Requirements of Turkeys as Percentages or as Milligrams or Units per Kilogram of Feed

		Age (weeks)							
		M: 0–4	4–8	8–12	12–16	16–20	20–24		Breeding
Energy Base		F: 0–4	4–8	8–11	11–14	14–17	17–20	Holding	Hens
kcal ME/kg Diet[a]	⟶	2,800	2,900	3,000	3,100	3,200	3,300	2,900	2,900
Protein	%	28	26	22	19	16.5	14	12	14
Arginine	%	1.6	1.5	1.25	1.1	0.95	0.8	0.6	0.6
Glycine + serine	%	1.0	0.9	0.8	0.7	0.6	0.5	0.4	0.5
Histidine	%	0.58	0.54	0.46	0.39	0.35	0.29	0.25	0.3
Isoleucine	%	1.1	1.0	0.85	0.75	0.65	0.55	0.45	0.5
Leucine	%	1.9	1.75	1.5	1.3	1.1	0.95	0.5	0.5
Lysine	%	1.6	1.5	1.3	1.0	0.8	0.65	0.5	0.6
Methionine + cystine	%	1.05	0.9	0.75	0.65	0.55	0.45	0.4	0.4
Methionine	%	0.53	0.45	0.38	0.33	0.28	0.23	0.2	0.2
Phenylalanine + tyrosine	%	1.8	1.65	1.4	1.2	1.05	0.9	0.8	1.0
Phenylalanine	%	1.0	0.9	0.8	0.7	0.6	0.5	0.4	0.55
Threonine	%	1.0	0.93	0.79	0.68	0.59	0.5	0.4	0.45
Tryptophan	%	0.26	0.24	0.2	0.18	0.15	0.13	0.1	0.13
Valine	%	1.2	1.1	0.94	0.8	0.7	0.6	0.5	0.58
Linoleic acid	%	1.0	1.0	0.8	0.8	0.8	0.8	0.8	1.0
Calcium	%	1.2	1.0	0.85	0.75	0.65	0.55	0.5	2.25
Phosphorus, available	%	0.6	0.5	0.42	0.38	0.32	0.28	0.25	0.35
Potassium	%	0.7	0.6	0.5	0.5	0.4	0.4	0.4	0.6
Sodium	%	0.17	0.15	0.12	0.12	0.12	0.12	0.12	0.15
Chlorine	%	0.15	0.14	0.14	0.12	0.12	0.12	0.12	0.12
Magnesium	mg	600	600	600	600	600	600	600	600
Manganese	mg	60	60	60	60	60	60	60	60
Zinc	mg	75	65	50	40	40	40	40	65
Iron	mg	80	60	60	60	50	50	50	60
Copper	mg	8	8	6	6	6	6	6	8
Iodine	mg	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4
Selenium	mg	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2
Vitamin A	IU	4,000	4,000	4,000	4,000	4,000	4,000	4,000	4,000
Vitamin D[b]	ICU	900	900	900	900	900	900	900	900
Vitamin E	IU	12	12	10	10	10	10	10	25
Vitamin K	mg	1.0	1.0	0.8	0.8	0.8	0.8	0.8	1.0
Riboflavin	mg	3.6	3.6	3.0	3.0	2.5	2.5	2.5	4.0
Pantothenic acid	mg	11.0	11.0	9.0	9.0	9.0	9.0	9.0	16.0
Niacin	mg	70.0	70.0	50.0	50.0	40.0	40.0	40.0	30.0
Vitamin B_{12}	mg	0.003	0.003	0.003	0.003	0.003	0.003	0.003	0.003
Choline	mg	1,900	1,600	1,300	1,100	950	800	800	1,000
Biotin	mg	0.2	0.2	0.15	0.125	0.100	0.100	0.100	0.15
Folacin	mg	1.0	1.0	0.8	0.8	0.7	0.7	0.7	1.0
Thiamin	mg	2.0	2.0	2.0	2.00	2.0	2.0	2.0	2.0
Pyridoxine	mg	4.5	4.5	3.5	3.5	3.0	3.0	3.0	4.0

[a] These are typical ME concentrations for corn-soya diets. Different ME values may be appropriate if other ingredients predominate.

[b] These concentrations of vitamin D are satisfactory when the dietary concentrations of calcium and available phosphorus conform with those in this table. See text, page 25–27.

TABLE 12 Growth Rate, Feed and Energy Consumption of Large-Type Turkeys

Age (weeks)	Body Weight (kg) M	Body Weight (kg) F	Feed Consumption per Week (kg) M	Feed Consumption per Week (kg) F	Cumulative Feed Consumption (kg) M	Cumulative Feed Consumption (kg) F	ME Consumption per Week (Mcal) M	ME Consumption per Week (Mcal) F
1	0.11	0.11	0.10	0.10	0.10	0.10	0.30	0.30
2	0.27	0.24	0.20	0.17	0.30	0.27	0.60	0.50
3	0.58	0.47	0.45	0.39	0.75	0.66	1.1	0.80
4	1.0	0.70	0.61	0.46	1.36	1.12	1.7	1.2
5	1.5	1.1	0.70	0.60	2.06	1.72	2.3	1.6
6	2.0	1.6	0.86	0.76	2.92	2.48	2.9	2.1
7	2.6	2.1	1.08	0.89	4.00	3.37	3.5	2.6
8	3.3	2.6	1.30	1.04	5.30	4.41	4.1	3.1
9	4.0	3.1	1.51	1.18	6.81	5.59	4.8	3.6
10	4.7	3.7	1.78	1.34	8.59	6.93	5.2	4.1
11	5.5	4.3	1.99	1.47	10.58	8.40	5.7	4.6
12	6.3	4.8	2.25	1.59	12.83	9.99	6.3	5.1
13	7.1	5.3	2.51	1.70	15.34	11.69	7.1	5.5
14	8.0	5.8	2.66	1.75	18.00	13.44	7.8	5.8
15	8.8	6.3	2.89	1.82	20.89	15.26	8.4	6.1
16	9.7	6.7	3.05	1.92	23.94	17.18	8.8	6.4
17	10.5	7.1	3.13	2.03	27.03	19.21	9.6	6.7
18	11.3	7.5	3.27	2.07	30.34	21.28	10.2	6.9
19	12.1	7.8	3.43	2.15	33.77	23.43	10.9	7.1
20	12.8	8.1	3.60	2.23	37.37	25.66	11.6	7.3
21	13.5	—	3.71	—	41.08	—	12.5	—
22	14.2	—	3.82	—	44.90	—	12.9	—
23	14.8	—	3.94	—	48.84	—	13.2	—
24	15.4	—	4.05	—	52.89	—	13.5	—

TABLE 13 Body Weights and Feed Consumption of Large-Type Turkeys During Holding and Breeding Periods[a]

Age (weeks)	Hens Weight (kg)	Hens Egg Production (%)	Hens Feed /Day (g)	Toms Weight (kg)	Toms Feed /Day (g)
20	7.0	—	200	12.0	400
25	8.0	—	215	13.5	420
30	9.0	Start light stimulation	230	16.0	440
35	9.5	66	260	17.0	450
40	9.3	63	255	18.0	460
45	9.1	60	250	18.2	480
50	9.0	50	240	18.5	500
55	9.0	40	230	18.8	510
60	9.0	35	220	19.0	520

[a]These values are based on experimental data involving "in season" egg production (i.e., November through July) of commercial stock. It is estimated that summer breeders would produce 70–90 percent as many eggs and consume 60–80 percent as much feed, respectively, as "in season" breeders.

5 Nutrient Requirements of Geese

Geese are reared under a variety of feeding programs. In the production of "farm geese," the goslings are given starter feed for about 2 weeks and then allowed to forage the farm for a variety of pasture and grain feedstuffs. Under these conditions they are marketable at about 18 weeks of age following liberal grain feeding for the last 2 or 3 weeks. In a second program the goslings are fed limited amounts of prepared feed throughout the growing period, but are still allowed considerable foraging. These geese are marketed at about 14 weeks of age following liberal feeding of a high-energy finishing diet. Geese may also be full-fed in confinement and marketed as "junior" or "green geese" at about 10 weeks of age. A fourth program is practiced in European countries and involves the production of goose livers for ***pâté de foie gras***. The geese are grown to about 12 weeks of age and are then force-fed a high-grain diet for the production of livers of high-fat content. The practice of force-feeding has been questioned on humane grounds. Geese for breeding purposes are fed holding and breeding diets for the intensive production of fertile eggs. The feeding of the prebreeding diets would commence 6 to 8 weeks before the breeding season.

As can be observed in Table 14, knowledge of the nutrient requirements of geese is sparse. More research is needed in areas of practical significance to goose production in North America.

TABLE 14 Nutrient Requirements of Geese as Percentages or as Milligrams or Units per Kilogram of Diet[a]

Energy Base kcal ME/kg Diet[b] →		Starting (0–6 Weeks) 2,900	Growing (After 6 weeks) 2,900	Breeding 2,900
Protein	%	22.0	*15.0*	*15.0*
Lysine	%	0.9	*0.6*	*0.6*
Methionine + cystine	%	0.75	—	—
Calcium	%	*0.8*	*0.6*	*2.25*
Phosphorus, available	%	*0.4*	*0.3*	*0.3*
Vitamin A	IU	*1,500*	*1,500*	*4,000*
Vitamin D	ICU	*200*	*200*	*200*
Riboflavin	mg	4.0	2.5	*4.0*
Pantothenic acid	mg	15.0	—	—
Niacin	mg	55.0	*35.0*	*20.0*

[a]For nutrients not listed, see requirements for chickens as a guide.
[b]These are typical dietary energy concentrations.

6 Nutrient Requirements of Ducks

Ducks are successfully grown in two environments—an open rearing system in which the growing house opens to an exercise yard with water for wading or swimming and a confinement growing system in which ducks are raised in environmentally controlled houses with litter or combination litter and wire floors.

Ducks consume pelleted diets more effectively than mash diets. They are typically provided with two or three feeds during the growing period. In the former case, a starter diet containing 22 percent protein is fed for 2 weeks, followed by a grower-finisher diet. In the latter, a 22 percent protein starter diet, 18 percent protein grower diet, and 16 percent protein finisher diet are provided. If ducklings are started with 16 percent protein, early growth may be retarded but compensatory growth leads to normal body size at market age.

TABLE 15 Nutrient Requirements of Pekin Ducks as Percentages or as Milligrams or Units per Kilogram of Diet[a]

Energy Base kcal ME/kg Diet[b] ⟶		Starting (0–2 weeks) 2,900	Growing (2–7 weeks) 2,900	Breeding 2,900
Protein	%	22.0	16.0	*15.0*
Arginine	%	1.1	1.0	—
Lysine	%	1.1	0.9	*0.7*
Methionine + cystine	%	0.8	0.6	*0.55*
Calcium	%	0.65	0.6	*2.75*
Phosphorus, available	%	0.40	0.35	*0.35*
Sodium	%	0.15	0.15	*0.15*
Chlorine	%	0.12	0.12	*0.12*
Magnesium	mg	*500*	*500*	*500*
Manganese	mg	40.0	40.0	*25.0*
Zinc	mg	60.0	60.0	*60.0*
Selenium	mg	*0.14*	*0.14*	*0.14*
Vitamin A	IU	*4,000*	*4,000*	*4,000*
Vitamin D	ICU	220	220	*500*
Vitamin K	mg	*0.4*	*0.4*	*0.4*
Riboflavin	mg	4.0	4.0	*4.0*
Pantothenic acid	mg	11.0	11.0	*10.0*
Niacin	mg	55.0	55.0	*40.0*
Pyridoxine	mg	2.6	2.6	*3.0*

[a]For nutrients not listed, see requirements for chickens as a guide.
[b]These are typical dietary energy concentrations.

TABLE 16 Typical Body Weights and Feed Consumption of Pekin Ducks to 8 Weeks of Age

Age (weeks)	Body Weight (kg)		Feed Consumption by 1-Week Periods (kg)		Cumulative Feed Consumption (kg)	
	M	F	M	F	M	F
0	0.05	0.05	—	—	—	—
1	0.27	0.27	0.22	0.22	0.22	0.22
2	0.78	0.74	0.77	0.73	0.99	0.95
3	1.38	1.28	1.12	1.11	2.11	2.05
4	1.96	1.82	1.28	1.28	3.40	3.33
5	2.49	2.30	1.48	1.43	4.87	4.76
6	2.96	2.73	1.63	1.59	6.50	6.35
7	3.34	3.06	1.68	1.63	8.18	7.98
8	3.61	3.29	1.68	1.63	9.86	9.61

7 Nutrient Requirements of Pheasants, Bobwhite Quail, and Japanese Quail

Nutrition and management are inseparable in the overall approach toward the rearing of these game birds. The requirements for many of the nutrients are not established for pheasants and Bobwhite quail. Diets formulated to meet the requirements for turkeys have been used successfully for pheasants and Japanese quail. Diets formulated for growing Leghorn-type chicks appear to satisfy the requirements for Bobwhite quail.

Pheasants and quail are fed diets designed to produce the type of bird required for specific markets, i.e., game-release farms or stores selling dressed game birds. Fast early growth is achieved with high-protein diets. Subsequently feeding of diets with lower-protein concentrations encourages the development of lean, flighty birds suitable for release. Pheasants fed either 20 percent or 30 percent of protein in the diet from the time of hatching will attain similar body weights by 20 weeks of age, although the higher protein concentration will allow the attainment of mature body weight at an earlier age. Japanese quail, which mature at 5 to 6 weeks of age, respond similarly to dietary protein concentration.

TABLE 17 Nutrient Requirements of Pheasants[a] and Bobwhite Quail[b] as Percentages or as Milligrams or Units per Kilogram of Diet

		Pheasant			Bobwhite Quail		
Energy Base kcal ME/kg Diet[c] →		Starting 2,800	Growing 2,700	Breeding 2,800	Starting 2,800	Growing 2,800	Breeding 2,800
Protein	%	30.0	16.0	18.0	28.0	20.0	24.0
Glycine + serine	%	*1.8*	*1.0*	—	—	—	—
Lysine	%	*1.5*	*0.8*	—	—	—	—
Methionine + cystine	%	*1.1*	*0.6*	*0.6*	—	—	—
Linoleic acid	%	*1.0*	*1.0*	*1.0*	*1.0*	*1.0*	*1.0*
Calcium	%	1.0	*0.7*	2.5	0.65	*0.65*	*2.3*
Phosphorus available	%	0.55	*0.45*	*0.40*	0.55	*0.45*	*0.50*
Sodium	%	*0.15*	*0.15*	*0.15*	*0.15*	*0.15*	*0.15*
Chlorine	%	0.11	*0.11*	*0.11*	*0.11*	*0.11*	*0.11*
Iodine	mg	*0.30*	*0.30*	*0.30*	0.30	*0.30*	*0.30*
Riboflavin	mg	*3.5*	*3.0*	—	*3.8*	—	*4.0*
Pantothenic acid	mg	10.0	*10.0*	—	13.0	—	*15.0*
Niacin	mg	60.0	*40.0*	—	30.0	—	*20.0*
Choline	mg	*1,500.0*	*1,000.0*	—	1,500.0	—	*1,000.0*

[a]For values not listed see requirements for turkeys as a guide.
[b]For values not listed see requirements for Leghorn-type chickens as a guide.
[c]These are typical dietary energy concentrations.

TABLE 18 Nutrient Requirements of Japanese Quail (Coturnix) as Percentage or as Milligrams or Units Per Kilogram of Diet

Energy Base kcal ME/kg diet[a] →		Starting and Growing 3,000	Breeding 3,000
Protein	%	24.0	*20.0*
Arginine	%	1.25	*1.26*
Glycine + serine	%	1.20	*1.17*
Histidine	%	0.36	*0.42*
Isoleucine	%	0.98	*0.90*
Leucine	%	1.69	*1.42*
Lysine	%	1.30	*1.15*
Methionine + cystine	%	0.75	*0.76*
Methionine	%	0.50	*0.45*
Phenylalanine + tyrosine	%	1.80	*1.40*
Phenylalanine	%	0.96	*0.78*
Threonine	%	1.02	*0.74*
Tryptophan	%	0.22	*0.19*
Valine	%	0.95	*0.92*
Linoleic acid	%	*1.0*	*1.0*
Calcium	%	0.8	2.5
Phosphorus, available	%	0.45	0.55
Potassium	%	*0.4*	*0.4*
Magnesium	mg	*300*	*500*
Sodium	%	*0.15*	*0.15*
Chlorine	%	*0.20*	*0.15*
Manganese	mg	*90*	*70*
Zinc	mg	25	*50*
Iron	mg	*100*	*60*
Copper	mg	*6*	*6*
Iodine	mg	*0.3*	*0.3*
Selenium	mg	*0.2*	*0.2*
Vitamin A	IU	*5,000*	*5,000*
Vitamin D	ICU	*1,200*	*1,200*
Vitamin E	IU	*12*	25
Vitamin K	mg	*1*	*1*
Riboflavin	mg	*4*	*4*
Pantothenic Acid	mg	*10*	*15*
Niacin	mg	40	*20*
Vitamin B_{12}	mg	*0.003*	*0.003*
Choline	mg	2,000	*1,500*
Biotin	mg	*0.3*	*0.15*
Folacin	mg	*1*	*1*
Thiamin	mg	*2*	*2*
Pyridoxine	mg	*3*	*3*

[a]These are typical dietary energy concentrations.

8 Signs of Nutritional Deficiencies in Chickens and Turkeys

This section describes the common signs of various nutritional deficiencies in poultry. Summaries are presented as a guide to identification of specific deficiencies on the basis of gross observations on embryos and growing birds. The signs indicated usually develop only with diets severely deficient in a single nutrient. Under field conditions, however, problems may be associated with marginal or multiple deficiencies. Diagnosis is accordingly often difficult. Unfortunately, a chronic deficiency that may be difficult to identify, and therefore to correct, can eventually cause more serious financial loss than an acute deficiency immediately diagnosed as to cause. Frequently deficiencies of many nutrients are associated only with nonspecific signs such as poor growth, general unthriftiness, poor feathering, lethargy, or lack of appetite. In some instances biochemical and physiological measurements can be used to assist in the diagnosis of nutrient deficiencies.

DIAGNOSTIC BIOCHEMICAL AND PHYSIOLOGICAL MEASUREMENTS

Over the past decade there has been an increasing interest in being able to monitor deficiencies of vitamins or minerals, or to identify clinical manifestations with particular vitamin or mineral deficiencies. Some enzymes are dependent on particular vitamins or minerals for their activities, and concentrations of these enzymes appear to be specific for monitoring these deficiencies. In other instances a particular physiological response or concentration in the blood may be the indicator. Table 19 summarizes the biochemical and physiological tests that may be useful in the diagnosis of nutrient deficiencies. Only some of the research contributing to the information in Table 19 has involved poultry. The applicability of the measurement from other species remains questionable. In such cases, the void in information should indicate fertile areas for research. Constantly improving technology and instrumentation, along with data on specificity of signs, should lead to routine laboratory procedures that one day will be readily available as guides in diagnosis of simple or complex deficiencies of vitamins and minerals.

SIGNS OF DEFICIENCY IN EMBRYOS

Deficiencies of some vitamins and minerals in the breeder diet are reflected in the composition of the egg and can result in poor hatchability. The age at which mortality occurs varies with the particular nutrient and with the concentration of the nutrient in the egg. Low maternal carry-over of vitamins and minerals may also be reflected in slow early growth of progeny. Embryonic mortality may occur without gross evidence of cause. The abnormalities shown in Table 20, however, have been observed in relation to nutrient deficiency. It should be noted that not all of the signs appear consistently.

SIGNS OF DEFICIENCY IN GROWING AND ADULT BIRDS

Characteristic signs of deficiency associated with individual nutrients are described below. Table 21 lists signs of deficiencies in growing birds by category as an aid in the diagnosis of vitamin and mineral deficiencies.

Amino Acid or Protein Deficiency

- Reduced feed intake.
- Growth depression.

TABLE 19 Biochemical and Physiological Measurements for Diagnosis of Nutrient Deficiencies

Nutrient	Biochemical or Physiological Measurement	References[a]
Vitamin A	Hepatic vitamin A is a good indicator, but blood vitamin A is not	Jensen, 1974; Rogers, 1969
Vitamin D	Ca-binding protein; ratio of $1,25(OH)_2D_3$ to $24,25(OH)_2D_3$ in serum (complicated by calcium and/or phosphorus level in diet); plasma alkaline phosphatase	Bar et al., 1972; Morrisey, 1977; Noguchi, 1973; Ohmdahl and DeLuca, 1973
Vitamin E	Superoxide dismutase; plasma and tissue vitamin E concentration	Arnold et al., 1974; Sklan et al., 1981; Sklan and Donoghue, 1982
Vitamin K	Prothrombin clotting time of blood	Griminger, 1965
Thiamin	Transketolase in erythrocytes and in leucocytes	Brin et al., 1960; Brin, 1964; Chang et al., 1976
Riboflavin	Erythrocyte glutathione reductase	Sauberlich et al., 1972; Tillotson and Sauberlich, 1971;
Pyridoxine	L-tryptophan loading; glutamate-oxaloacetate-transaminase (GOT); glutamate-pyruvate-transaminase (GPT); leucine transaminase; aspartate aminotransferase	Daghir, 1976; Kazemi and Kratzer, 1980; Lee et al., 1976; Sauberlich et al., 1972; Shiflett and Haskill, 1971; Sifri et al., 1972; Thiele and Brin, 1968
Folacin	Dihydrofolate reductase in liver; serine hydroxymethyl transferase	Rabani et al., 1973; Zamierowski and Wagner, 1977
Vitamin B_{12}	B_{12} in blood; urinary excretion of methylmalonic acid	Barnes et al., 1963; Cox and White, 1962; Lau et al., 1965
Pantothenic acid	Coenzyme A in red blood cells and liver	Sauberlich et al., 1974; Williams et al., 1968
Biotin	Blood pyruvate carboxylase; the ratio of $C_{16:1}/C_{18:0}$ fatty acids in blood	Edwards, 1974; Whitehead and Bannister, 1980
Choline	^{14}C uptake into phosphatidylethanolamine and phosphatidylcholine after I.V. injection of ^{14}C-ethanolamine (complicated by dietary levels of fat, methionine, folic acid, and vitamin B_{12})	Anon. 1981; Haines and Rose, 1970
Linoleic acid	Linoleate, arachidonate, and eicosatrienoate concentrations in liver lipids	Machlin and Gordon, 1960
Calcium	Calcium in hen's blood (but not in chick's unless deficiency severe); intestinal calcium-binding protein (complicated by D_3 metabolites and phosphorus); turkey poults differ from chicks	Bar et al., 1972, 1978a, 1978b; Bar and Hurwitz, 1973; Buckner et al., 1930
Chloride	Hemoconcentration; alkalosis	Cohen and Hurwitz, 1974; Hamilton and Thompson, 1980; Leach and Nesheim, 1963
Copper	Plasma ceruloplasmin; lysyl oxidase in aorta, liver, tendon, and bone	Kim and Hill, 1966; Miller and Stake, 1974; Opsahl et al., 1982
Iodine	Plasma thyroxine and tri-iodothyronine	Singh et al., 1968
Iron	Hematocrit; blood hemoglobin concentration; transferrin saturation; anemia with lipemia	Amine et al., 1976; Davis et al., 1962; Planas, 1967; McNaughton and Day, 1979
Magnesium	Mg concentrations in blood	Hajj and Sell, 1969; Sell et al., 1967
Manganese	Chondroitin sulfate in bone; manganese concentration in bone; superoxide dismutase	de Rosa et al., 1980; Leach, 1968; Reid et al., 1973
Phosphorus	Serum inorganic P; renal calcium-binding protein	Bar et al., 1978a, 1978b; Miller and Stake, 1974
Potassium	Plasma K; metabolic acidosis (complicated by Na)	Burns et al., 1953; Cohen and Hurwitz, 1974
Selenium	Plasma glutathionine peroxidase	Dean and Combs, 1981; Noguchi et al., 1973
Sodium	Metabolic acidosis (complicated by K)	Cohen and Hurwitz, 1974; Nott and Combs, 1966
Zinc	Plasma and bone zinc; thymidine kinase; alkaline phosphatase and collagenase in bone	Bettger et al., 1981; Miller and Stake, 1974; Oberleas and Prasad, 1974, Starcher et al., 1980

[a]These references are shown on pp. 53–54.

TABLE 20 Embryonic Signs of Deficiency

Nutrient	Sign
Vitamin A	Early mortality—failure of development of circulatory system
Vitamin D	Stunting, soft bones, shortened upper mandible
Vitamin E	Late mortality—hemorrhages and disturbances in circulatory system
Riboflavin	Mortality peak in middle of incubation period—dwarfing, edema, clubbed down
Pantothenic acid	Mortality generally late and without characteristic sign—subcutaneous hemorrhages, abnormal feathering
Biotin	Skeletal deformities including shortened, twisted bones of legs, feet and wings (micromelia), skull deformities, crooked (parrot) beak, webbing between toes (syndactyly)
Folacin	Mortality generally late and without characteristic signs—bent tibiotarsus, syndactyly, parrot beak
Vitamin B_{12}	Edema, shortening of beak, poor muscle development (myoatrophy of legs), perosis, hemorrhages
Manganese	Shortened leg bones, perosis, skull deformities, parrot beak
Zinc	Faulty spine and limb development, caudal part of trunk absent, portions of or entire limbs missing, small eyes (microphthalmia), abnormalities of beak and other head structures
Iodine	Enlarged thyroid glands, incomplete closure of navel, prolonged incubation time
Iron	Low hematocrit values, low blood hemoglobin concentration; pale, poorly visible extraembryonic circulation in candled eggs

- Abnormal feather development.
- Tongue deformity in growing birds with leucine, isoleucine, and phenylalanine deficiency.
- Lack of melanin pigment in black- or reddish-colored feathers with lysine deficiency.
- Decline in egg production (hatchability unaffected).
- Reduction in egg size.
- Resorption of ova in severe deficiency.
- Body weight loss in severe deficiency.

Vitamin A

Early signs of vitamin A deficiency in chicks include ataxia, poor growth, and poor feather formation. Vitamin A is required for the development and maintenance of normal epithelial tissue. The eye condition known as xerophthalmia may lead to bacterial invasion. The involvement of the epithelial tissue increases susceptibility to infection from parasites such as coccidia and roundworms. A typical sign of vitamin A deficiency seen upon post mortem examination is the distention of the kidney tubules and ureters with urates. Chronic deficiency in the adult is referred to as "nutritional roup" because of the discharge from the eyes and nostrils. Egg production is reduced in vitamin A deficiency.

Vitamin A is potentially toxic, and excessive dietary concentrations can be harmful to chicks and poults. Concentrations over 50,000 IU/kg of diet fed to layers have been reported to result in pale yolk color. Higher concentrations may induce blood spots in eggs and will cause a decline in egg production.

A number of naturally occurring plant carotenoids can be utilized by the bird for conversion to vitamin A. Of these, β-carotene has the greatest activity as a precursor of vitamin A; cryptoxanthin, α-carotene, and γ-carotene are less potent.

Vitamin A is subject to oxidative destruction. Most preparations used as feed supplements are stabilized to extend the time over which their activity is maintained. It is, nevertheless, common practice to supplement at levels somewhat above the actual requirement.

Vitamin D

Vitamin D is essential for regulation of calcium absorption from the digestive tract and for the deposition of calcium in and withdrawal of calcium from bone. Vitamin D_2 (ergosterol) is only about 1/30 to 1/40 as effective for birds as vitamin D_3 (cholecalciferol).

Both these forms of vitamin D are modified in the body to derivatives that perform the biochemical functions formerly attributed to dietary vitamin D. The absorbed vitamin D is first altered in the liver to $25(OH)D_3$. It is further altered in the kidney to $1{,}25(OH)_2D_3$. Additional chemical forms also have been identified. Birds exposed to direct sunlight will synthesize adequate amounts of vitamin D_3 from sterol present in the skin. In the absence of ultraviolet light, however, growing birds deficient in vitamin D will develop rickets. The bones and the beak fail to calcify and become soft and rubbery; rib ends may also become "beaded." Growth and feathering will be adversely affected. With certain feather color patterns, primarily ermine, an abnormal blackening of the feathers develops.

Laying birds fed a vitamin D-deficient diet will produce eggs with increasingly thin shells until eventually many eggs will be shell-less. Egg production will decline. The bones will demineralize, and the birds may eventually be unable to stand. The egg size and hatchability may be affected. Embryonic mortality at 18 to 19 days is usual with the embryos showing a short upper mandible or incomplete formation of the base of the beak.

TABLE 21 Nutrients Associated with Various Signs of Deficiencies in Growing Birds[a]

Deficiency Sign	Description	Species	Associated Vitamin or Mineral
Skin lesions	Crusting and scab formation around eyes and beak	Chick, poult	Biotin, pantothenic acid
	Bottoms of feet rough and calloused with hemorrhagic cracks	Chick, poult	Biotin, pantothenic acid
	Scaliness on feet	Chick	Zinc, niacin
	Lesions around eyes, eyelids stuck together	Chick, poult	Vitamin A
	Mouth, inflammation of oral mucosa (chicken black tongue)	Poult, chick	Niacin
Feather abnormalities	Uneven feather growth, abnormally long primary feathers, feathers not lying smoothly	Chick, poult	Protein, amino acid imbalance
	Frizzled and rough	Chick, poult	Zinc, niacin, panthothenic acid, folic acid
	Black pigmentation in breeds with red and brown feathers	Chick	Vitamin D
	Depigmentation	Chick, poult	Copper, iron, folacin
Nervous disorders	Convulsions with head retraction	Chick, pigeon	Thiamin
	Convulsions with hyperexcitability	Chick, poult, duckling	Pyridoxine
	Hyperirritability	Chick, poult, duckling	Magnesium, sodium chloride
	Characterisic fright reaction with tetanic spasms	Chick	Chloride
	Spastic cervical paralysis, neck extended with birds appearing to look down	Poult	Folacin
	Curled-toe paralysis, gross enlargement of sciatic and brachial nerves with myelin degeneration	Chick	Riboflavin
	Encephalomalacia, tetanic spasms with head retraction, hemorrhagic lesions in cerebellum	Chick	Vitamin E
Blood and vascular system	Anemia	All poultry	
	Macrocytic		Vitamin B_{12}
	Macrocytic, hyperchromic		Folacin
	Microcytic, hypochromic		Iron, copper
	Microcytic		Pyridoxine
	Hemorrhage, intramuscular, subcutaneous, internal from aortic rupture	Chick, poult	Vitamin K, copper
	Exudative diathesis	Chick, poult	Selenium, vitamin E
	Enlarged heart	Chick, poult	Copper
Muscle	Muscular dystrophy, white areas of degeneration in skeletal muscle	Chick, duck, poult	Vitamin E, selenium
	Cardiac myopathy	Poult	Vitamin E, selenium
	Gizzard myopathy	Poult	Vitamin E, selenium
Bone disorders	Soft, easily bent bones and beak (rickets)	All poultry	Vitamin D, calcium or phosphorus deficiency or imbalance
	Hock enlargement	Poult, chick, gosling, duckling	Niacin, zinc
	Perosis	Chick, poult	Biotin, choline, vitamin B_{12}, manganese, zinc, folacin
	Bowed legs	Duck	Niacin
	Shortening and thickening of leg bones	Chick	Zinc, manganese
	Curled toes	Chick	Riboflavin
Diarrhea		Chick, duck, poult	Niacin, riboflavin, biotin

[a]Slow growth and general lack of vigor are generally associated with malnutrition. These signs are more specific indications of deficiences of particular nutrients.

Although vitamin D is toxic at high concentrations, as much as 100 times the requirement level may be tolerated.

Vitamin E

Vitamin E deficiency in chicks may result in encephalomalacia, exudative diathesis, or muscular dystrophy. The signs of encephalomalacia are sudden prostration with legs outstretched, toes flexed, and head retracted, frequently with lateral twisting. Movement is incoordinated and gait is affected before more severe signs are apparent. Postmortem examination reveals necrotic, reddish or brownish lesions in the cerebellum and often in the cerebrum.

Exudative diathesis is a condition in which there is subcutaneous edema and/or edema of the heart and pericardium. It is caused by an increase in capillary permeability permitting accumulation of exudates that have a protein pattern similar to that in blood plasma or serum. Usually exudate accumulates under the skin over the breast. The exudates are characteristically greenish in color from degeneration of hemoglobin.

Nutritional muscular dystrophy, or myopathy, occurs in the presence of combined deficiencies of vitamin E and selenium. A deficiency of sulfur amino acids also contributes to the development of the disease. The breast muscle is most commonly affected but degeneration may occur in other muscles. The functions of vitamin E and selenium are related in protection against muscular dystrophy and exudative diathesis. In the presence of low vitamin E, selenium will prevent muscular dystrophy and exudative diathesis, but not encephalomalacia.

Prolonged vitamin E deficiency in cockerels causes permanent sterility. Hatchability of eggs from vitamin E-deficient hens is reduced. Embryonic mortality may be high during the first 4 days of incubation as a result of circulatory failure. Mortality may also occur late in the incubation period and in the chicks after hatching. Poults deficient in vitamin E develop a nutritional myopathy characterized by lesions in the muscular wall of the gizzard. Circumscribed gray areas occur. These often are of firmer texture than the normal muscle and sometimes resemble scar tissue. In vitamin E-deficient turkey embryos the eyes may protrude with a bulging of the cornea. A yellowish-white spot appears between the lens and the cornea at 24 to 28 days incubation. Eye hemorrhages and cataracts occur with liquifaction of the lens protein.

Vitamin K

A lack of vitamin K lengthens the time required for blood to clot. Chicks fed a deficient ration may bleed to death from even a slight injury. Hemorrhages may occur subcutaneously, intramuscularly, or internally. Hemorrhaging is the only gross evidence of deficiency. If a deficiency of vitamin K is suspected, blood samples may be tested for clotting time by the prothrombin test.

Mature birds are not subject to acute vitamin K deficiency and chicks showing prolonged clotting time as a result of vitamin K deficiency generally recover spontaneously, provided hemorrhaging is not induced. Absorption of vitamin K synthesized by bacteria in the intestine usually provides sufficient vitamin K to meet the needs of the bird. It has been shown, however, that breeders fed a diet low in vitamin K may produce eggs that are low in the vitamin. Chicks hatched from such eggs will have low reserves of vitamin K. As a consequence, the chicks may bleed to death from an injury as slight as that caused by wing-banding.

Antimicrobial agents such as sulfa drugs suppress intestinal bacteria that synthesize vitamin K. In the presence of antimicrobial agents, the bird may be entirely dependent upon vitamin K supplied in the diet. Arsanilic acid increases the need for dietary vitamin K in both breeder and chick diets.

There are a number of chemically related compounds with vitamin K activity. Both biological activity and solubility vary among these compounds.

Thiamin

Day-old chicks, adult chickens, and turkeys placed on thiamin-deficient diets develop polyneuritis within 9 to 12 days. Early signs are lethargy and head tremors. In the acute stage of polyneuritis, chicks show a retraction of the head over the back. Other signs are loss of appetite, emaciation, general weakness, and often convulsions.

Grains and grain by-products are good sources of thiamin, and with grain-based poultry diets thiamin deficiency is unusual. Infection of grain with certain molds may result in destruction of thiamin. Stability can be a problem in purified diets. Occasionally thiamin deficiency may develop in birds infected with specific intestinal bacteria possessing thiaminase activity which destroys dietary thiamin before it can be absorbed.

Riboflavin

A lack of riboflavin in the diet of young chicks results in diarrhea, retardation of growth, and leg paralysis of the type described as curled-toe paralysis. The chicks characteristically walk on their hocks, with toes curling inward. The paralysis may cause some chicks to walk on their hocks without the toes being curled. The carriage of the bird in walking and standing may be affected so that instead of being erect the bird carries its head, tail, and wings low. Chicks fed a diet only marginally deficient in riboflavin often recover spontaneously. The condition is curable in the early stages, but in its acute stage it is irreversible. In severe cases, the brachial and sciatic nerves are greatly enlarged and lesions appear in the myelin sheath of these nerves. Riboflavin deficiency in breeding hens causes low hatchability. The requirement for hatchability is considerably higher than for egg production and health of the bird.

Riboflavin-deficient embryos that have failed to hatch are dwarfed and show a high incidence of edema, degeneration of the Wolffian bodies, and a defect in down development described as "clubbed down." A breeder diet, moderately deficient in riboflavin, will result in considerable embryonic mortality during the second week of incubation.

Niacin

A deficiency of niacin in the chick diet results in a condition known as "black tongue," characterized by inflammation of the tongue and mouth cavity. Beginning at about 2 weeks of age, the entire mouth cavity, as well as the upper part of the esophagus, becomes distinctly inflamed, growth is retarded, and feed consumption declines. There is poor feather development and occasionally a scaly dermatitis occurs on the feet and head.

Poults fed a diet deficient in niacin develop a hock disorder. The same condition occurs, but less frequently, in niacin-deficient chicks. Poults, pheasant chicks, goslings, and ducklings have higher requirements for niacin than chicks. Accordingly, the feeding of chick starting and growing diets to these other species may result in leg problems.

The niacin present in cereal grains and grain byproducts varies in availability and should probably be disregarded in calculating the concentration of available niacin in a diet.

Biotin

Biotin deficiency in chicks results in dermatitis with considerable variation in time of appearance of the signs. The bottoms of the feet become rough and calloused with hemorrhagic cracks. The foot problem is usually exacerbated by bacterial invasion of the lesions. The toes may become necrotic and slough off, but the tops of the feet and the legs usually show only a dry scaliness. Mandibular lesions first appear at the corners of the mouth and then spread to include the area around the beak. Eyelids become swollen and stick together. The signs are somewhat similar to those of pantothenic acid deficiency with the difference that in pantothenic acid deficiency the lesions are first evident in the corners of the mouth and around the eyes, and only in severe deficiency are there pronounced lesions on the feet.

Biotin deficiency is reportedly a cause of hock disorders in both poults and chicks. In poults usual signs of deficiency include bending of the metatarsus, broken flight feathers, and dermatitis of the footpads and toes, base of the beak, eye ring, and vent.

Signs of biotin deficiency in laying hens have not been reported. Breeder diets deficient in biotin reduce hatchability but do not usually affect egg production. Biotin-deficient embryos display parrot beak, micromelia, and syndactyly.

Biotin deficiency has been implicated in fatty liver and kidney syndrome (FLKS). This condition may cause mortality as high as 30 percent in chicks fed practical diets containing wheat or barley as the cereal grain. In such diets biotin is not fully available, and FLKS is responsive to dietary supplementation with biotin. The classical signs of biotin deficiency are not usually observed in chicks with FLKS. The lipid content of the liver and kidneys is elevated.

The availability of biotin from wheat and barley is poor and birds fed rations formulated with these grains may respond to biotin supplementation of the ration. Even with corn-based diets, however, poults may require dietary supplementation with biotin. Mold infection of feeds has been implicated in promoting biotin deficiency, possibly through formation of an antimetabolite to biotin. Biotin deficiency may also result from the destruction of the vitamin in the presence of rancid dietary fat.

Pantothenic Acid

Pantothenic acid deficiency in chicks results in growth retardation and ragged feathers. Dermatitis is apparent at 12 to 14 days. The eyelids become granular and are stuck together with a viscous exudate. Crusty scabs appear at the corners of the mouth and around the vent. Dermatitis of the feet is evident over the toes (in contrast to biotin deficiency, which primarily affects the foot pads) and is seldom as severe as in biotin deficiency. Liver damage and changes in the spinal cord are sometimes found upon postmortem examination.

As with other vitamins, the requirement of the breeder hen for pantothenic acid exceeds that for egg production and the health of the bird. In the absence of adequate pantothenic acid in the breeder diet hatchability is reduced and chicks that hatch may be too weak to survive. Embryonic mortality in pantothenic acid deficiency occurs usually during the last few days of incubation.

Pyridoxine (Vitamin B_6)

Chicks fed a diet deficient in vitamin B_6 have little appetite and grow slowly. A more specific sign of deficiency is the nature of the nervous condition that develops. The deficient chicks are abnormally excitable. They display uncontrollable random running accompanied by constant cheeping and convulsions during which the chick may rest on its breast, raise its feet off the floor and flap its wings or fall on its side, or roll over on its back and rapidly paddle its feet. The head often retracts and sometimes moves convulsively up and down with the neck extended or twisted. Violent convulsions cause complete exhaustion and may lead to death.

Vitamin B_6 deficiency in adult birds fed practical diets is rare. When it occurs it results in loss of appetite and a consequent rapid decline in body weight. Egg production and hatchability are reduced, and death ultimately occurs.

Folacin

Folacin deficiency in chicks results in slow growth, poor feathering, loss of feather pigmentation, and anemia. The anemia of folacin deficiency in the chicken is characterized by a reduction in the number of red blood cells and in the blood concentration of hemoglobin. The red blood cells are malformed, larger than normal, and contain more hemoglobin than do normal cells.

Folacin deficiency in the diet of chicken breeders reduces both egg production and hatchability. Folacin-deficient embryos show bending of the tibiotarsus, defects of the mandible, syndactyly, and hemorrhages.

Poults suffering from folacin deficiency are nervous and their wings droop. Some exhibit a characteristic cervical paralysis in which the neck is stiff and extended. When cervical paralysis develops the affected poults usually die within 2 days.

Turkey breeder hens fed a folacin-deficient diet show normal egg production but reduced hatchability of the eggs. Embryonic mortality occurs during the last days of incubation. The embryonic signs of deficiency include micromelia, twisted hocks, mandibular defects, enlarged, fluid-filled gizzards, hemorrhages, and edema.

Vitamin B_{12}

Vitamin B_{12} is essential for maximum growth of chicks and poults. Deficiency causes anemia and gizzard erosion. Fattiness of the heart, liver, and kidneys and perosis may result. Marginal dietary concentrations will cause poor feathering. Vitamin B_{12} is required in the breeder diet for hatchability. Deficient embryos show hemorrhages and edema. Chicks that hatch without adequate carryover of vitamin B_{12} from the dam may have a high rate of mortality.

Birds obtain some vitamin B_{12} by absorption of the vitamin produced by bacterial synthesis in the intestine. The amount from this source is not reliable, however, and diets for young chicks and poults as well as for breeding hens require dietary supplementation if the diet contains no natural sources.

Choline

Growth retardation and perosis are induced by choline deficiency in chicks, poults, and ducklings. Adult chickens probably synthesize sufficient choline to meet the requirements for egg production. Despite lack of evidence that laying chickens require a dietary source of choline for maximum egg production, the addition of choline to practical rations markedly reduces the amount of fat in the liver. Supplementary choline may be necessary for maintenance of egg size in quail. Likewise the dietary requirement for choline by growing quail appears to be higher than that for chicks or poults.

Calcium and Phosphorus

Bone formation is highly dependent on the dietary concentrations of calcium and phosphorus as well as on adequate intake of vitamin D. Deficiency of any one of these nutrients will result in rickets. Poor growth may also be a sign of calcium and phosphorus deficiency.

Dietary excesses of both calcium and phosphorus should be avoided since the intestinal absorption of other mineral elements may be hindered. Phosphorus availability from plant products, where it occurs in the form of phytin, is of serious nutritional concern. Not only may phytin phosphorus itself be poorly available, but phytin may bind calcium, zinc, iron, and manganese so as to render them unavailable also.

Pullets, at the beginning of the laying period, undergo considerable metabolic stress associated with adjustment to the need to supply approximately 2.4 grams of calcium daily to the oviduct for shell formation. Some birds mobilize large amounts of calcium from their skeleton during this period to the extent that the bones may become so demineralized that the birds are unable to stand and appear paralyzed. The sternum and rib bones are frequently deformed, and all bones are easily broken. Dietary management to prevent this condition (generally termed "cage-layer fatigue" but more precisely described as osteoporosis) has not been devised.

Magnesium

When fed a diet very deficient in magnesium, chicks grow slowly for about 1 week, and then stop growing and become lethargic. Chicks fed diets marginal in magnesium may grow quite well, but will exhibit reduced levels of plasma magnesium and symptoms of neuromuscular hyperirritability when disturbed. Chicks show a brief convulsion and then enter a comatose state from which they usually recover, but sometimes death occurs. A magnesium deficiency in laying hens results in a rapid decline in blood magnesium level, withdrawal of magnesium from bone, decline in egg production, and, eventually, a comatose state and death. Magnesium content and hatchability of eggs also are reduced when hens are fed magnesium-deficient diets. Increasing either the calcium or phosphorus content of the diets accentuates magnesium deficiency. Normally, adequate magnesium is present in the natural ingredients of practical diets to meet the requirements of poultry.

Manganese

Manganese deficiency in chicks or poults results in perosis or slipped tendon. Deficiencies of other nutrients, e.g., choline and biotin, may also be involved in inducing perosis. Perosis is a malformation of the bones. The signs usually observed are swelling and flattening of the hock joint, with subsequent slipping of the Achilles tendon from its condyles. The tibia and the tarsometatarsus may exhibit bending near the hock joint and lateral rotation. One or both legs may be affected. A shortening and thickening of the long bones of the wings and legs are also observed. The disorder, insofar as manganese is concerned, is aggravated by excess dietary calcium and phosphorus.

In laying and breeding birds, manganese deficiency results in lowered egg production, reduced egg shell strength, and poor hatchability. Manganese-deficient embryos exhibit shortening of the long bones, parrot beak, and wiry down.

Potassium, Sodium, Chloride

A deficiency of potassium results in high mortality and retarded growth of chicks and causes reduced egg production and egg shell thickness in laying hens. It is not generally necessary to add potassium to practical feed formulations, since such formulas generally contain about 0.7 to 1.0 percent potassium.

A deficiency of sodium in chicken diets results in decreased egg production, poor growth, and cannibalism. Frequently the sodium level is reduced to minimal levels to reduce the moisture level in the excreta.

Signs of chloride deficiency in chicks include poor growth, mortality, hemoconcentration, and reduced blood chloride level. Chloride-deficient chicks show a nervous condition resembling tetany and fall forward with legs extended backward when stimulated by a sharp noise.

Iodine

Iodine is necessary for the synthesis of thyroid hormones. Iodine deficiency results in goiter, i.e., enlargement of the thyroid glands. The glands may increase to many times their usual size. If the deficiency is not too severe, the increased efficiency of the enlarged gland in "trapping" iodine from the bloodstream may compensate for the low dietary concentration. When this is the case, the production of thyroid hormones is normal although the thyroid glands are enlarged.

Inadequate production of thyroid hormones results in poor growth, egg production, and egg size. Iodine deficiency in breeders results in low iodine content of the egg and, consequently, decreased hatchability and thyroid enlargement in the embryos.

Copper

Copper deficiency in poultry causes an anemia in which the red blood cells are small and low in hemoglobin. Bone deformities can occur. Pigmentation of feathers in New Hampshire and Rhode Island Red chickens is reduced. Copper is required for the activity of the enzyme needed for the cross-linking of lysine in the protein elastin. Dissecting aneurism of the aorta occurs in birds deficient in copper because of the defect in elastin formation. Copper deficiency in turkey poults results in marked cardiac hypertrophy.

Iron

Iron deficiency in chickens and turkeys causes an anemia in which the red blood cells are reduced in size and low in hemoglobin. In red-feathered chickens pigmentation does not occur when the diet is deficient in iron.

Selenium

Selenium is closely associated with vitamin E and other antioxidants in practical feed formulation. The principal sign of deficiency in chicks is exudative diathesis. A requirement for selenium supplementation, even in the presence of vitamin E, is demonstrated by the poor growth and mortality of chicks fed purified diets or diets based on grains produced on low-selenium soils. Selenium is required for prevention of myopathies of the gizzard and heart in turkeys. Pancreatic fibrosis, with resultant reductions in pancreatic output of lipase, trypsinogen, and chymotrypsinogen, has also been associated with deficiency. Selenium is a structural component of glutathione peroxidase.

It should be noted that there is wide variability in the amount of selenium in the soils of different geographic areas. Consequently, cereals and plant-derived feedstuffs are variable sources of selenium. Grains from some areas contain sufficient selenium to render them toxic to chicks. The effects of toxic levels of selenium are listed in Table 22. The amount of supplementary selenium permissable in rations is regulated in the United States and Canada.

Zinc

Zinc has many biochemical functions. Deficiency causes retarded growth and frayed feathers. The extent of fraying varies from almost no feathers on the wings and tail to only slight defects in the development of some of the barbules and barbicels. The long bones of the legs and wings are shorter and thicker than normal. The hock joint may be enlarged. Layer and breeder diets deficient in zinc will lower egg production and hatchability. Zinc-deficient embryos exhibit a wide variety of skeletal abnormalities involving the head, limbs, and vertebrae.

9 Toxic Levels of Elements

Current information on toxic dietary levels of inorganic elements for poultry is summarized in Table 22. Toxicity, as defined here, is any adverse effect on performance of poultry. Reduced growth rate is the most common physiological effect used to indicate the specific level at which a particular element is toxic. Although most of the information was obtained from experiments in which the element was added in the form of an inorganic compound, organic compounds served as the source of elements in some reports. For instance, some of the information on the toxicity of selenium was obtained by feeding seleniferous wheat. Toxicity of an element is influenced by the nature of the compound in which it is present (e.g., methyl mercury is much more toxic than mercuric chloride). Also, toxicity may be influenced markedly by composition of the diet, particularly with respect to the content of other mineral elements. Selenium included in the diet at 10 ppm reduces growth rate, but when fed in combination with 1,000 ppm silver, a level as high as 40 ppm does not reduce growth. Copper at a level of 800 ppm in a practical turkey diet is not toxic, but 50 ppm of copper in a purified diet reduces growth. The toxicity of copper is modified by the sulfur amino acid content of the diet. In many instances, a high dietary level of one element will antagonize another, resulting in a physiological deficiency of elements essential for the animal. Because of the factors that affect the quantity of an element needed to produce toxicity, diverse observations have been reported on the toxic effect of the different elements. Original reports are cited for the convenience of the reader wishing to consult them.

TABLE 22 Toxic Dietary Concentrations of Inorganic Elements for Poultry

Element	Species	Age	Chemical Form	Toxic Concentration (ppm)[a]	Effects	Reference[b]
Aluminum	Chicken	Immature	$AlCl_2$	500	Reduced growth	Storer and Nelson, 1968
Aluminum	Chicken	Immature	$Al_2(SO_4)_3$	1,000	Reduced growth	Storer and Nelson, 1968
Aluminum	Chicken	Immature	$Al_2(SO_4)_3$	2,200	Rickets	Deobold and Elvehjem, 1935
Arsenic	Chicken	Laying hen	As_2O_5	100	Reduced body weight; reduced egg production	Hermayer et al., 1977
Barium	Chicken	Immature	$BaCO_3$, $BaCl_2$	200	Reduced growth	Taucins et al., 1969
Barium	Chicken	Immature	$BaCl_2$	2,000	Death	Taucins et al., 1969
Bromine	Chicken	Immature	NaBr	5,000	Reduced growth	Doberenz et al., 1965
Cadmium	Chicken	Immature	$CdSO_4 \cdot H_2O$	25	Reduced growth	Hill et al., 1963
Cadmium	Chick	Immature	$CdSO_4$	40	Reduced growth	Hill, 1974
Cadmium	Turkey	Immature	$CdCl_2$	20	Reduced growth	Supplee et al., 1961
Cadmium	Chicken	Adult	$CdSO_4$	12	Decreased egg production	Leach et al., 1979
Chloride	Chicken	Immature	Arginine · HCL, NaCl and KCl	15,000	Reduced growth	Nesheim et al., 1964
Chromium	Chicken	Immature	K_2CrO_4	300	Reduced growth	Kunishisa et al., 1966
Chromium	Chicken	Immature	$Cr_2(SO_4)_3$	300	Reduced growth	Kunishisa et al., 1966
Cobalt	Chicken	Immature	$CoCl_2 \cdot 6H_2O$	200	Reduced growth	Hill, 1974
Copper	Chicken	Immature	CuO	806	Reduced growth; mortality	Mehring et al., 1960
Copper	Chicken	Immature	$CuSO_4 \cdot 5H_2O$	800	Exudative diathesis; muscular dystrophy	Jensen, 1975a
Copper	Chicken	Immature	$CuSO_4 \cdot 5H_2O$	500	Reduced growth; gizzard erosion	Poupoulis and Jensen, 1976
Copper	Chicken	Immature	$CuSO_4 \cdot 5H_2O$	250	Reduced growth; gizzard erosion	Robbins and Baker, 1980
Copper	Turkey	Immature	$CuSO_4 \cdot 5H_2O$	676 (practical diet)	Reduced growth	Vohra and Kratzer, 1968
Copper	Turkey	Immature	$CuSO_4 \cdot 5H_2O$	800 (purified diet)	Reduced growth	Supplee, 1964
Copper	Turkey	Immature	$CuCO_3$	50 (purified diet) 800 (practical diet not toxic)	Reduced growth	Waibel et al., 1964
Fluorine	Chicken	Immature	NaF	1,000	Reduced growth	Dobernez et al., 1965
Fluorine	Chicken	Immature	NaF	500 (similar level of F as CaF not toxic)	Reduced growth	Gardiner et al., 1959
Fluorine	Chicken	Immature	NaF	500	Reduced growth	Weber, 1969
Fluorine	Chicken	Immature	NaF	750	Reduced growth	Berg and Martinson, 1972
Fluorine	Turkey	Immature	NaF	400	Reduced growth	Nahorniak et al., 1983
Iodine	Chicken	Laying hen	KI	625	Reduced egg production, egg size, and hatchability	Arrington et al., 1967
Iron	Chicken	Immature	$Fe_2(SO_4)_3$	4,500	Rickets	Deobold and Elvehjem, 1935
Lead	Chicken	Immature	Pb acetate	1,000	Reduced growth	Damron et al., 1969
Lead	Chicken	Immature	Pb acetate	300	Lethargy, 50% mortality	Vengris and Mare, 1974
Magnesium	Chicken	Immature	$MgCO_3$	6,000	Reduced growth	Chicco et al., 1967
Magnesium	Chicken	Immature	$MgCO_3$	6,400	Reduced growth; mortality	Nugara and Edwards, 1963
Magnesium	Chicken	Adult	$MgSO_4$	19,600	Reduced egg production	McWard, 1967
Magnesium	Chicken	Adult	$MgCO_3$	11,200	Reduced egg production	Stillmak and Sunde, 1971
Manganese	Turkey	Immature	$MnSO_4 \cdot H_2O$	4,800	Reduced growth	Vohra and Kratzer, 1968
Mercury	Chicken	Immature	$HgSO_4$, $HgCl_2$	400	Reduced growth	Hill 1964; Hill et al., 1964
Mercury	Chicken	Immature	$HgCl_2$	250[c]	Reduced growth; mortality	Parkhurst and Thaxton, 1973
Mercury	Chicken	Immature	CH_3Hg dicyanamide	33	Reduced growth; mortality	Gardiner, 1972
Mercury	Chicken	Immature	CH_3HgCl	5	50% mortality	Soares et al., 1973
Molybdenum	Chicken	Immature	Na_2MoO_4	500	Reduced growth; mortality	Davies et al., 1960
Molybdenum	Chicken	Immature	$Na_2MoO_4 \cdot 2H_2O$	350	Reduced growth	Berg and Martinson, 1972
Molybdenum	Chicken	Laying hen	$Na_2MoO_4 \cdot 2H_2O$	500	Reduced egg production and hatchability	Lepore and Miller, 1965
Molybdenum	Turkey	Immature	$NaMoO_4$	300	Reduced growth	Kratzer, 1952
Nickel	Chicken	Immature	$NiSO_4$ or Ni acetate	500	Reduced growth	Weber and Reid, 1968
Nitrate	Turkey	Immature	$NaNO_3$	900[c]	Reduced growth; mortality	Adams et al., 1967
Nitrate	Turkey	Immature	$NaNO_3$	450 (N)[c]	No effect on meat color	Mugler et al., 1970
Nitrite	Chicken	Immature	KNO_2	658 (N)	Decreased vitamin A in liver and thyroid enlargement	Sell and Roberts, 1963
Selenium	Chicken	Immature	Na_2SeO_3 + Se wheat	10	Reduced growth	Carlson and Leitis, 1957
Selenium	Chicken	Immature	Na_2SeO_3	10	Reduced growth	Jensen, 1975b
Selenium	Chicken	Immature	Na_2SeO_3	20 (with 1,000 Ca)	Reduced growth	Jensen, 1975b
Selenium	Chicken	Laying hen	Se wheat	10	Reduced hatchability	Moxon and Wilson, 1944
Selenium	Chicken	Adult	Na_2SeO_3	5	Decreased hatchability	Ort and Latshaw, 1978
Silver	Chicken	Immature	$AgSO_4$	200	Reduced growth	Hill, 1964
Silver	Chicken	Immature	$AgNO_3$	900	Exudative diathesis (prevented by Se or vitamin E)	Peterson and Jensen, 1975a

TABLE 22 (*Continued*)

Element	Species	Age	Chemical Form	Toxic Concentration (ppm)[a]	Effects	Reference[b]
Silver	Chicken	Immature	$AgNO_3$	900	Anemia, enlarged hearts	Peterson and Jensen, 1975b
Silver	Turkey	Immature	Ag acetate or nitrate	900	Anemia, enlarged hearts and muscular dystrophy (prevented by Cu + Se)	Jensen et al., 1974
Sodium	Chicken	Immature	Na glutamate	8,900[d]	Reduced growth	Nesheim et al., 1964
Sodium	Chicken	Laying hen	Na_2SO_4	12,000[c]	Reduced egg production	Krista et al., 1964
Sodium chloride	Chicken	Immature	NaCl	7,000[c]	Reduced growth; mortality	Krista et al., 1961
Sodium chloride	Chicken	Laying hen	NaCl	10,000[c]	Reduced egg production	Krista et al., 1961
Sodium chloride	Turkey	Immature	NaCl	4,000[c]	Reduced body weight; mortality	Krista et al., 1961
Sodium chloride	Turkey	Immature	NaCl	27,000	Lung congestion; enlarged kidneys; mortality	Morrison et al., 1975
Sodium chloride	Duck	Immature	NaCl	4,000[c]	Reduced body weight	Krista et al., 1961
Sodium chloride	Turkey	Mature	NaCl	60,000	Reduced growth	Roberts, 1957
Sodium chloride	Turkey	Immature	NaCl	40,000	Reduced growth; pendulous crop	Harper and Arscott, 1962
Strontium	Chicken	Immature	$SrCO_3$	6,000	Reduced growth	Weber et al., 1968
Sulfate	Chicken	Immature	K_2SO_4, Na_2SO_4, $CaSO_4$	14,000	Reduced growth	Leach et al., 1960
Sulfate	Chicken	Laying hen	Na_2SO_4	8,100	Reduced egg production	Krista et al., 1961
Tungsten	Chicken	Immature	Sodium tungstate	500	Reduced growth	Teekell and Watts, 1959
Vanadium	Chicken	Immature	NH_4VO_3	8	Reduced growth	Berg, 1963
Vanadium	Chicken	Immature	$Ca_3(VO_4)_2$	30	Reduced growth	Romoser et al., 1961
Vanadium	Chicken	Immature	$Ca_3(VO_4)_2$	200	Mortality	Romoser et al., 1961
Vanadium	Chicken	Immature	NH_4VO_3 or $VOSO_4$	25	Reduced growth; mortality	Hathcock et al., 1964
Vanadium	Chicken	Immature	$NaVO_3$	5	Reduced growth	Hill, 1974
Vanadium	Chicken	Immature	NH_4VO_3	10	Reduced growth	Summers and Moran, 1972
Vanadium	Chicken	Laying hen	V in dicalcium phosphate	6	Depressed albumin quality	Sell et al., 1982
Vanadium	Chicken	Laying hen	NH_4VO_3	15	Depressed albumin quality	Berg et al., 1963
Vanadium	Chicken	Laying hen	NH_4VO_3	20	Depressed albumin quality; reduced body weight	Berg et al., 1963
Vanadium	Chicken	Laying hen	NH_4VO_3	30	Depressed egg production	Berg et al., 1963
Vanadium	Chicken	Laying hen	NH_4VO_3	50	Depressed hatchability	Berg et al., 1963
Zinc	Chicken	Immature	$ZnSO_4$, $ZnCO_3$	1,500	Reduced growth	Roberson and Schaible, 1960
Zinc	Chicken	Immature	ZnO	3,000	Reduced growth	Johnson et al., 1962
Zinc	Chicken	Immature	ZnO	800	Reduced growth; bone ash (sucrose-fish meal diet)	Berg and Martinson, 1972
Zinc	Chicken	Immature	$ZnSO_4$	2,000	Exudative diathesis; muscular dystrophy	Jensen, 1975a
Zinc	Chicken	Immature	$ZnSO_4$	3,000	Reduced growth (0.5 ppm Se in diet)	Jensen, 1975a
Zinc	Turkey	Immature	ZnO	4,000	Reduced growth	Vohra and Kratzer, 1968

[a]Dietary concentrations of the elements unless specified otherwise.
[b]These references are shown on pp. 54–56.
[c]In water.
[d]Diet low in Cl^- ion.

10 Composition of Feedstuffs Used in Poultry Diets

Feed formulation involves the correlation of the nutrient requirements of the bird with the amounts of the various nutrients present in the feed ingredients to be used in formulating a diet. If nutrient concentrations found in composition tables are erroneously high, diets formulated on the basis of those values will be deficient even though the dietary concentrations are calculated to satisfy the requirements. The desirable solution to the problem would be the actual analysis of each batch of feedstuff before its use in diet formulation. Because of the impracticality of this solution, some reliance must be placed on tabled values for the nutrient composition of feedstuffs. In using the tables it should be recognized that feedstuffs available in particular areas may differ from those described in the tables.

Feedstuffs are of varied composition. The values given in the following tables are averages reflecting the concentrations of nutrients most likely to be present in the feedstuffs commonly used in poultry feeds. The major source of information on the nutrient composition is the *United States-Canadian Tables of Feed Composition*, 3rd Revision, 1982. Data have also been obtained from commercial suppliers, from the Association of American Feed Control Officials, and from individual scientists.

VARIABILITY IN CEREAL GRAINS

Bushel weights (bulk densities) of cereal grains are used in commerce to establish market grades and prices. Bushel weights of grains also have been used as criteria of feeding value, and in some instances this practice seems justified for poultry. For example, at standard moisture levels there is a strong relationship between bushel weight and general feeding value of oats and barley. An increase in bushel weight of these grains is a reflection of an increase in the proportion of the meaty kernel and a decrease in the proportion of fibrous hull. Thus, there is a definite increase in metabolizable energy, and usually protein, content of barley and oats as bushel weight increases. Similarly, there seems to be a direct relationship between the metabolizable energy content of grain sorghum and wheat as bushel weight increases over a wide range. A relationship between bushel weight and the metabolizable energy content of corn is not so evident. In situations where corn, sorghum, or wheat fail to achieve maturity because of early frost or early harvest, there usually are decreases in the starchy endosperm portion of the grain. Bushel weight and metabolizable energy content are usually low. Table 23 indicates the ranges in bushel weight that may be encountered with different grains.

Notwithstanding differences in bushel weight, the protein content of grains (dry matter basis) often varies a great deal from batch to batch. This variation may be the result of differences in genetic constitution, soil fertility, time of harvest, and other factors. Protein concentrations of grains can be determined readily for feed formulation purposes. It should be recognized, however, that the amino acid composition of protein in a specific grain does not remain constant as protein concentration changes. In some instances, the concentrations of

TABLE 23 Ranges in Weights per Bushel for Different Grains

	lb/bushel	kg/hectoliter
Barley	36–48	46–62
Corn	46–56	59–72
Sorghum (milo)	51–57	66–74
Oats	22–40	28–52
Soybeans	49–56	63–72
Wheat	45–63	58–81

TABLE 24 Composition (Excluding Amino Acids) of Some Feeds Commonly Used for Poultry; Data on As-Fed Basis

Entry Number	Feed Name Description	International Feed Number[a]	Dry Matter (%)	ME_n (kcal/kg)	Protein (%)	Ether Extract (%)	Linoleic Acid (%)	Crude Fiber (%)	Calcium (%)	Total Phosphorus (%)	Non-phytate Phosphorus (%)	Potassium (%)	Chlorine (%)
	ALFALFA *Medicago sativa*												
01	meal dehydrated, 17% protein	1-00-023	92	1370	17.5	2.0	0.47	24.1	1.44	0.22	0.22	2.17	0.47
02	meal dehydrated, 20% protein	1-00-024	92	1630	20.0	3.6	0.58	20.2	1.67	0.28	—	2.21	0.47
	BAKERY												
03	waste, dehydrated (dried bakery product)	4-00-466	92	3862	9.8	11.7	—	1.2	0.13	0.24	—	0.49	1.48
	BARLEY *Hordeum vulgare*												
04	grain	4-00-549	89	2640	11.6	1.8	0.83	5.1	0.03	0.36	0.16	0.48	0.15
05	grain, pacific coast	4-07-939	89	2620	9.0	2.0	0.85	6.4	0.05	0.32	—	0.53	0.15
	BROADBEAN *Vicia faba*												
06	seeds	5-09-262	87	2431	23.6	1.4	—	6.7	0.11	—	—	—	—
	BLOOD												
07	meal, vat dried	5-00-380	94	2830	81.1	1.6	—	0.5	0.55	0.42	—	0.09	0.27
08	meal, spray or ring dried	5-00-381	93	3420	88.9	1.0	0.10	0.6	0.06	0.09	—	0.41	0.27
	BREWERS GRAINS												
09	dehydrated	5-02-141	92	2080	25.3	6.2	2.94	15.3	0.29	0.52	—	0.09	0.12
	BUCKWHEAT, COMMON *Fagopyrum sagittatum*												
10	grain	4-00-994	88	2660	10.8	2.5	—	10.5	0.09	0.32	0.12	0.40	0.04
	CANE MOLASSES—SEE MOLASSES												
	CANOLA *Brassica napus-Brassica campestris*												
11	seeds, meal prepressed solvent extracted, low erucic acid, low glucosinolates	5-06-145	93	2000	38.0	3.8	—	11.1	0.68	1.17	0.30	1.29	—
	CASEIN												
12	dehydrated	5-01-162	93	4130	87.2	0.8	—	0.2	0.61	1.00	—	0.01	—
13	precipitated dehydrated	5-20-837	92	4118	85.0	0.6	—	0.2	0.68	0.82	—	0.01	—
	CORN, DENT YELLOW *Zea mays indentata*												
14	distillers grains, dehydrated	5-28-235	94	1972	27.8	9.2	—	11.3	0.10	0.40	—	0.17	0.07
15	distillers grains with solubles, dehydrated	5-28-236	93	2480	27.4	9.0	4.55	9.1	0.17	0.72	0.41	0.65	0.17
16	distillers solubles, dehydrated	5-28-237	92	2930	28.5	9.0	4.55	4.0	0.35	1.33	1.24	1.75	0.26
17	gluten, meal, 60% protein	5-28-242	90	3720	62.0	2.5	—	1.3	—	0.50	0.19	0.35	0.05
18	gluten with bran (corn gluten feed)	5-28-243	90	1750	22.0	2.5	—	8.0	0.40	0.80	—	0.57	0.22
19	grain	4-02-935	89	3350	8.8	3.8	2.20	2.2	0.02	0.28	0.10	0.30	0.04
20	grits by-product (hominy feed)	4-03-011	90	2896	10.4	6.9	3.28	6.0	0.05	0.52	—	0.59	0.05
	COTTON *Gossypium* spp												
21	seeds, meal mechanically extracted, 41% protein (expeller)	5-01-617	93	2320	40.9	3.9	2.47	10.8	0.20	1.05	—	1.19	0.04
22	seeds, meal prepressed solvent extracted, 41% protein	5-07-872	90	2400	41.4	0.5	—	13.6	0.15	0.97	0.29	1.22	0.03
23	seeds, meal prepressed solvent extracted, 44% protein	5-07-873	91	1857	44.7	1.6	—	11.1	0.15	0.91	—	—	—
	FEATHERS—SEE POULTRY												
	FISH												
24	solubles, condensed	5-01-969	51	1460	31.5	7.8	—	0.2	0.30	0.76	—	1.74	2.65
25	solubles, dehydrated	5-01-971	92	2830	63.6	9.3	0.12	0.5	1.23	1.63	—	0.37	—
	FISH, ANCHOVY *Engraulis ringen*												
26	meal mechanically extracted	5-01-985	92	2580	64.2	5.0	0.20	1.0	3.73	2.43	—	0.69	0.29
	FISH, HERRING *Clupea harengus*												
27	meal mechanically extracted	5-02-000	93	3190	72.3	10.0	0.15	0.7	2.29	1.70	—	1.09	0.90
	FISH, MENHADEN *Brevoortia tyrannus*												
28	meal mechanically extracted	5-02-009	92	2820	60.5	9.4	0.12	0.7	5.11	2.88	—	0.77	0.60
	FISH, WHITE Gadidae (family)-Lophiidae (family)-Rajidae (family)												
29	meal mechanically extracted	5-02-025	91	2593	62.6	4.6	0.08	0.7	7.31	3.81	—	0.83	0.50
	GELATIN												
30	process residue (gelatin by-products)	5-14-503	91	2360	88.0	0.0	—	—	0.50	Trace	—	—	—
	HOMINY FEED—SEE CORN												
	LIVERS												
31	meal	5-00-389	92	2860	65.6	15.0	—	1.4	0.56	1.25	—	—	—
	MEAT												
32	meal rendered	5-00-385	92	2000	54.4	7.1	0.28	8.7	8.27	4.10	—	0.60	0.91
33	with bone, meal rendered	5-00-388	93	1960	50.4	8.6	0.36	2.8	10.30	5.10	—	1.02	0.74
	MILLET, PEARL *Pennisetum glaucum*												
34	grain	4-03-118	91	2554	13.1	4.3	0.84	4.3	0.05	0.32	—	0.43	0.14
	MILLET, PROSO *Panicum miliaceum*												

Entry Number	Iron (mg/kg)	Magnesium (%)	Manganese (mg/kg)	Sodium (%)	Sulfur (%)	Copper (mg/kg)	Selenium (mg/kg)	Zinc (mg/kg)	Biotin (mg/kg)	Choline (mg/kg)	Folic Acid (Folacin) (mg/kg)	Niacin (mg/kg)	Pantothenic Acid (mg/kg)	Vitamin B6 (Pyridoxine) (mg/kg)	Riboflavin (mg/kg)	Thiamin (mg/kg)	Vitamin B12 (μg/kg)	Vitamin E (mg/kg)
01	480	0.36	30	0.12	0.17	10	0.34	24	0.30	1401	4.2	38	25.0	6.5	13.6	3.4	4	125
02	390	0.36	42	0.13	0.43	11	0.29	25	0.33	1419	3.3	40	34.0	8.0	15.2	5.8	4	144
03	28	0.24	65	1.14	0.02	5	—	15	0.07	923	0.2	26	8.3	4.3	1.4	2.9	—	41
04	50	0.14	16	0.04	0.15	10	0.10	17	0.15	990	0.7	55	8.0	3.0	1.8	1.9	—	20
05	110	0.12	16	0.02	0.15	8	0.10	15	0.15	1034	0.5	48	7.0	2.9	1.6	4.0	—	20
06	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
07	2020	0.16	5	0.32	0.32	10	0.01	4	0.08	695	0.1	29	3.0	4.4	2.6	0.4	44	—
08	3000	0.40	6	0.33	0.32	8	—	306	0.20	280	0.4	13	5.0	4.4	1.3	0.5	44	—
09	250	0.16	38	0.15	0.31	21	0.70	98	0.96	1723	7.1	29	8.0	0.7	1.4	0.5	—	25
10	44	0.09	34	0.05	0.14	10	—	9	—	440	—	19	12.0	—	5.5	4.0	—	—
11	159	0.64	54	—	—	10	1.00	71	0.90	6700	2.3	160	9.5	—	3.7	5.2	—	—
12	18	0.01	4	0.01	—	4	—	33	0.05	205	0.5	1	3.0	0.4	1.5	0.5	—	—
13	17	0.01	4	0.01	—	4	—	32	0.04	208	0.5	1	2.7	0.4	1.5	0.4	—	—
14	209	0.07	22	0.09	0.43	45	0.45	33	0.49	1180	0.9	37	11.7	4.4	5.2	1.7	—	—
15	280	0.19	24	0.48	0.30	57	0.39	80	0.78	2637	0.9	71	11.0	2.2	8.6	2.9	—	40
16	560	0.64	74	0.26	0.37	83	0.33	85	1.10	4842	1.1	116	21.0	10.0	17.0	6.9	3	55
17	400	0.15	4	0.02	0.43	26	1.00	33	0.15	330	0.2	55	3.0	6.2	2.2	0.3	—	24
18	460	0.29	24	0.95	0.22	48	0.10	7	0.33	1518	0.3	66	17.0	15.0	2.4	2.0	—	15
19	350	0.12	5	0.02	0.08	3	0.03	10	0.06	620	0.4	24	4.0	7.0	1.0	3.5	—	22
20	67	0.24	15	0.08	0.03	14	0.10	3	0.13	1155	0.3	47	8.2	11.0	2.1	8.1	—	—
21	160	0.52	23	0.04	0.40	19	0.06	64	0.60	2753	1.0	38	10.0	5.3	5.1	6.4	—	39
22	110	0.40	20	0.04	0.31	18	—	82	0.55	2933	2.7	40	7.0	3.0	4.0	3.3	—	—
23	—	—	—	—	—	—	—	—	—	2685	0.9	46	14.5	—	4.7	—	—	—
24	160	0.02	14	2.62	0.12	45	2.00	38	0.18	3519	0.2	169	35.0	12.2	14.6	5.5	347	—
25	300	0.30	50	0.37	0.40	—	—	76	0.26	5507	0.6	271	55.0	23.8	7.7	7.4	401	6
26	220	0.24	10	0.88	0.54	9	1.36	103	0.23	4408	0.2	100	15.0	4.0	7.1	0.1	352	4
27	140	0.15	5	0.61	0.69	6	1.93	132	0.31	5306	0.8	93	17.0	4.0	9.9	0.1	403	22
28	440	0.16	33	0.41	0.45	11	2.10	147	0.20	3056	0.6	55	9.0	4.0	4.9	0.5	104	7
29	181	0.18	12	0.78	0.48	6	1.62	90	0.08	3099	0.3	59	9.9	5.9	9.1	1.7	90	9
30	—	0.05	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
31	630	—	9	—	—	89	—	—	0.02	11311	5.5	204	29.0	—	46.3	0.2	498	—
32	440	0.58	10	1.15	0.49	10	0.42	103	0.17	2077	0.3	57	5.0	3.0	5.5	0.2	68	1
33	490	1.12	14	0.72	0.50	2	0.25	93	0.64	1996	0.3	46	4.1	12.8	4.4	0.8	70	1
34	25	0.16	31	0.04	0.13	22	—	13	—	793	—	53	7.8	—	1.6	6.7	—	—

TABLE 24 Composition (Excluding Amino Acids) of Some Feeds Commonly Used for Poultry; Data on As-Fed Basis—*Continued*

Entry Number	Feed Name Description	International Feed Number[a]	Dry Matter (%)	MEn (kcal/kg)	Protein (%)	Ether Extract (%)	Linoleic Acid (%)	Crude Fiber (%)	Calcium (%)	Total Phosphorus (%)	Non-phytate Phosphorus (%)	Potassium (%)	Chlorine (%)
35	grain	4-03-120	90	2898	11.6	3.5	—	6.1	0.03	0.30	0.14	0.43	—
	OATS *Avena sativa*												
36	grain	4-03-309	89	2550	11.4	4.2	1.47	10.8	0.06	0.27	0.12	0.45	0.11
37	grain, pacific coast	4-07-999	91	2610	9.0	5.0	—	11.0	0.08	0.30	—	0.37	0.12
38	hulls	1-03-281	92	400	4.6	1.4	—	28.7	0.13	0.10	—	0.53	0.10
	PEA *Pisum* spp												
39	seeds	5-03-600	90	2570	23.8	1.3	—	5.5	0.11	0.42	—	1.02	0.06
	PEANUT *Arachis hypogaea*												
40	kernels, meal mechanically extracted (peanut meal) (expeller)	5-03-649	90	2500	39.8	7.3	1.43	13.0	0.16	0.56	—	1.13	0.03
41	kernels, meal solvent extracted (peanut meal)	5-03-650	92	2200	50.7	1.2	0.24	11.9	0.20	0.63	0.36	1.19	0.03
	POULTRY												
42	by-product, meal rendered (viscera with feet and heads)	5-03-798	93	2670	58.0	13.0	2.54	2.0	3.00	1.70	—	0.30	0.54
43	feathers, meal hydrolyzed	5-03-795	93	2360	86.4	3.3	—	1.0	0.33	0.55	—	0.31	0.28
	RICE *Oryza sativa*												
44	bran with germ (rice bran)	4-03-928	91	2100	12.9	13.0	3.57	11.4	0.07	1.50	0.21	1.73	0.07
45	grain, polished and broken (Brewers rice)	4-03-932	89	2990	8.7	0.7	—	9.8	0.08	—	—	0.00	0.08
46	polishings	4-03-943	90	3090	12.2	11.0	3.58	4.1	0.05	1.31	0.14	1.06	0.11
	RYE *Secale cereale*												
47	grain	4-04-047	88	2626	12.1	1.5	—	2.2	0.06	0.32	0.08	0.46	0.03
	SAFFLOWER *Carthamus tinctorius*												
48	seeds, meal solvent extracted	5-04-110	92	1193	23.4	1.4	—	30.0	0.34	0.75	—	0.76	—
49	seeds without hulls, meal solvent extracted	5-07-959	92	1921	43.0	1.3	—	13.5	0.35	1.29	0.40	1.10	0.16
	SESAME *Sesamum indicum*												
50	seeds, meal mechanically extracted (expeller)	5-04-220	93	2210	43.8	8.6	1.90	9.7	1.99	1.37	0.26	1.20	0.06
	SORGHUM *Sorghum bicolor*												
51	grain, 8–10% protein	4-20-893	87	3288	8.8	2.9	1.13	2.3	0.04	0.30	—	0.35	—
52	grain, more than 10% protein	4-20-894	88	3212	11.0	2.1	0.82	2.3	0.04	0.32	—	0.33	—
	SOYBEAN *Glycine max*												
53	flour by-product (soybean mill feed)	4-04-594	89	720	13.3	1.6	—	33.0	0.37	0.19	—	1.50	—
54	protein concentrate, more than 70% protein	5-08-038	93	3500	84.1	0.4	—	0.2	0.02	0.80	0.32	0.18	0.02
55	seeds, heat processed	5-04-597	90	3300	37.0	18.0	8.46	5.5	0.25	0.58	—	1.61	0.03
56	seeds, meal solvent extracted	5-04-604	89	2230	44.0	0.8	0.40	7.3	0.29	0.65	0.27	2.00	0.05
57	seeds without hulls, meal solvent extracted	5-04-612	90	2440	48.5	1.0	0.40	3.9	0.27	0.62	0.24	2.02	0.05
	SUNFLOWER, COMMON *Helianthus annuus*												
58	seeds, meal solvent extracted	5-09-340	90	1543	23.3	1.1	0.60	31.6	0.21	0.93	0.14	0.96	—
59	seeds without hulls, meal solvent extracted	5-04-739	93	2320	45.4	2.9	1.59	12.2	0.37	1.00	—	1.00	0.10
	TRITICALE *Triticale hexaploide*												
60	grain	4-20-362	90	3163	15.8	1.5	—	4.0	0.05	0.30	0.11	0.36	—
	WHEAT *Triticum aestivum*												
61	bran	4-05-190	89	1300	15.7	3.0	1.70	11.0	0.14	1.15	0.34	1.19	0.06
62	flour by-product, less than 4% fiber (wheat red dog)	4-05-203	88	2568	15.3	3.3	—	2.6	0.04	0.49	—	0.51	0.14
63	flour by-product, less than 9.5% fiber (wheat middlings)	4-05-205	88	1800	16.0	3.0	1.87	7.5	0.12	0.90	0.23	0.99	0.03
64	flour by-product, less than 7% fiber (wheat shorts)	4-05-201	88	2162	16.5	4.6	—	6.8	0.09	0.81	—	0.93	0.07
65	grain, hard red winter	4-05-268	87	2800	14.1	1.9	0.59	2.4	0.05	0.37	0.11	0.45	0.05
66	grain, soft white winter	4-05-337	89	3120	10.2	1.8	—	2.4	0.05	0.31	—	0.40	0.08
	WHEY *Bos taurus*												
67	dehydrated	4-01-182	93	1900	12.0	0.8	0.01	0.2	0.97	0.76	—	1.05	0.07
68	low lactose, dehydrated (dried whey product)	4-01-186	91	2090	15.5	1.0	0.01	0.3	1.95	0.98	—	3.00	2.10
	YEAST, BREWERS *Saccharomyces cerevisiae*												
69	dehydrated	7-05-527	93	1990	44.4	1.0	—	2.7	0.12	1.40	—	1.70	0.12
	YEAST, TORULA *Torulopsis utilis*												
70	dehydrated	7-05-534	93	2160	47.2	2.5	0.05	2.4	0.58	1.67	—	1.88	0.02

[a] First digit is class of feed: 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; the other five digits are the International Feed Number.

Entry Number	Iron (mg/kg)	Magnesium (%)	Manganese (mg/kg)	Sodium (%)	Sulfur (%)	Copper (mg/kg)	Selenium (mg/kg)	Zinc (mg/kg)	Biotin (mg/kg)	Choline (mg/kg)	Folic Acid (Folacin) (mg/kg)	Niacin (mg/kg)	Pantothenic Acid (mg/kg)	Vitamin B6 (Pyridoxine) (mg/kg)	Riboflavin (mg/kg)	Thiamin (mg/kg)	Vitamin B12 (μg/kg)	Vitamin E (mg/kg)
35	71	0.16	—	—	—	—	—	—	—	440	—	23	11.0	—	3.8	7.3	—	—
36	70	0.16	43	0.08	0.21	8	0.30	17	0.11	946	0.3	12	7.8	1.0	1.1	6.0	—	20
37	73	0.17	38	0.06	0.20	—	0.07	—	0.11	959	0.3	14	13.0	1.3	1.1	—	—	20
38	100	0.08	14	0.04	0.14	3	—	0.1	—	284	1.0	7	3.0	2.2	1.5	0.6	—	—
39	50	0.13	—	0.04	—	—	—	30	0.18	642	0.4	34	10.0	1.0	2.3	7.5	—	3
40	156	0.33	25	0.07	0.29	15	0.28	20	0.76	1655	0.4	166	47.0	10.0	5.2	7.1	—	3
41	142	0.04	29	0.07	0.30	15	—	20	0.39	2396	0.4	170	53.0	10.0	11.0	5.7	—	3
42	440	0.22	11	0.40	0.51	14	0.75	120	0.30	5952	1.0	40	12.3	4.4	11.0	1.0	310	2
43	76	0.20	21	0.71	1.50	7	0.84	54	0.44	891	0.2	27	10.0	3.0	2.1	0.1	78	—
44	190	0.95	324	0.07	0.18	13	0.40	30	0.42	1135	2.2	293	23.0	14.0	2.5	22.5	—	60
45	—	0.11	18	0.07	0.06	—	0.27	17	0.08	800	0.2	46	8.0	—	0.7	1.4	—	14
46	160	0.65	12	0.10	0.17	3	—	26	0.61	1237	0.2	520	47.0	—	1.8	19.8	—	90
47	60	0.12	58	0.02	0.15	7	0.38	31	0.06	419	0.6	19	8.0	2.6	1.6	3.6	—	15
48	495	0.35	18	0.05	0.13	10	—	41	1.43	820	0.5	11	33.9	—	2.3	—	—	1
49	484	1.02	39	0.04	0.20	9	—	33	1.67	3248	1.6	22	39.1	11.3	2.4	4.5	—	1
50	93	0.77	48	0.04	0.43	—	—	100	0.34	1536	—	30	6.0	12.5	3.6	2.8	—	—
51	—	0.15	15	0.01	0.08	—	—	—	0.26	668	0.2	41	12.4	5.2	1.3	3.9	—	7
52	—	0.12	—	0.01	0.11	—	—	—	—	—	—	—	—	—	1.1	—	—	—
53	—	0.12	29	0.25	0.06	—	—	—	0.22	640	0.3	24	13.0	2.2	3.5	2.2	—	—
54	130	0.01	1	0.07	0.71	7	0.10	23	0.3	2	2.5	6	4.2	5.4	1.2	0.2	—	—
55	80	0.28	30	0.03	0.22	16	0.11	16	0.27	2860	4.2	22	11.0	10.8	2.6	11.0	—	40
56	120	0.27	29	0.04	0.43	22	0.10	27	0.32	2794	1.3	29	16.0	6.0	2.9	4.5	—	2
57	—	—	43	0.03	—	15	0.10	45	0.32	2731	3.6	22	15.0	5.0	2.9	3.2	—	3
58	—	0.68	—	—	0.30	—	—	—	—	3791	—	264	29.9	11.1	3.0	3.0	—	—
59	30	0.75	23	2.00	—	4	—	—	1.45	2894	—	220	24.0	16.0	4.7	3.1	—	11
60	44	—	43	—	0.15	8	—	32	—	462	—	—	—	—	0.4	—	—	—
61	170	0.52	113	0.05	0.22	14	0.85	133	0.48	1880	1.2	186	31.0	7.0	4.6	8.0	—	14
62	46	0.16	55	0.04	0.24	6	0.30	65	0.11	1534	0.8	42	13.3	4.6	2.2	22.8	—	33
63	40	0.16	118	0.12	0.26	18	0.80	150	0.37	1439	0.8	98	13.0	9.0	2.2	16.5	—	40
64	73	0.25	117	0.02	0.20	12	0.43	109	—	1813	1.7	107	22.3	7.2	4.2	19.1	—	54
65	50	0.17	32	0.04	0.12	6	0.20	31	0.11	1090	0.4	48	9.9	3.4	1.4	4.5	—	13
66	40	0.10	24	0.04	0.12	7	0.06	28	0.11	1002	0.4	57	11.0	4.0	1.2	4.3	—	13
67	130	0.13	6	0.48	1.04	46	0.08	3	0.34	1369	0.8	10	44.0	4.0	27.1	4.1	23	0.2
68	238	0.25	8	1.50	1.05	7	0.10	7	0.64	4392	1.4	19	69.0	4.0	45.8	5.7	23	—
69	120	0.23	5	0.07	0.38	33	1.00	39	1.05	3984	9.9	448	109.0	42.8	37.0	91.8	1	2
70	90	0.13	13	0.01	0.34	14	1.00	99	1.39	2881	22.4	500	73.0	36.3	47.7	6.2	4	—

TABLE 25 Amino Acid Composition of Some Feeds Commonly Used for Poultry; Data on As-Fed Basis

Entry Number	Feed Name Description	International Feed Number[a]	Dry Matter (%)	Protein (%)	Arginine (%)	Glycine (%)	Serine (%)	Histidine (%)	Isoleucine (%)	Leucine (%)	Lysine (%)	Methionine (%)	Cystine (%)	Phenylalanine (%)	Tyrosine (%)	Threonine (%)	Tryptophan (%)	Valine (%)
	ALFALFA *Medicago sativa*																	
01	meal dehydrated, 17% protein	1-00-023	92	17.5	0.80	0.90	0.77	0.32	0.84	1.26	0.73	0.23	0.20	0.79	0.56	0.70	0.28	0.84
02	meal dehydrated, 20% protein	1-00-024	92	20.0	0.92	0.97	0.89	0.34	0.88	1.30	0.87	0.31	0.25	0.85	0.59	0.76	0.33	0.97
	BAKERY																	
03	waste, dehydrated (dried bakery product)	4-00-466	92	9.8	0.47	0.82	0.65	0.13	0.45	0.73	0.31	0.17	0.17	0.40	0.41	0.49	0.10	0.42
	BARLEY *Hordeum vulgare*																	
04	grain	4-00-549	89	11.6	0.59	0.40	0.42	0.29	0.49	0.80	0.40	0.17	0.19	0.64	0.33	0.42	0.14	0.62
05	grain, pacific coast	4-07-939	89	9.0	0.48	0.36	0.32	0.21	0.40	0.60	0.29	0.13	0.18	0.48	0.31	0.30	0.12	0.46
	BROADBEAN *Vicia faba*																	
06	seeds	5-09-262	87	23.6	1.05	0.55	0.04	0.28	0.51	0.94	0.78	0.01	—	0.03	0.03	0.49	0.23	0.58
	BLOOD																	
07	meal, vat dried	5-00-380	94	81.1	3.63	4.59	3.14	3.52	0.95	10.53	7.05	0.55	0.52	5.66	2.07	3.15	1.29	7.28
08	meal, spray or ring dried	5-00-381	93	88.9	3.81	4.00	3.86	5.26	0.88	11.82	8.85	0.75	0.86	6.55	2.49	3.94	1.34	8.60
	BREWERS GRAINS																	
09	dehydrated	5-02-141	92	25.3	1.28	1.09	0.80	0.57	1.44	2.48	0.90	0.57	0.39	1.45	1.19	0.98	0.34	1.66
	BUCKWHEAT, COMMON *Fagopyrum sagittatum*																	
10	grain	4-00-994	88	10.8	1.02	0.71	0.41	0.26	0.37	0.56	0.61	0.20	0.20	0.44	0.21	0.46	0.19	0.54
	CANOLA *Brassica napus-Brassica campestris*																	
11	seeds, meal prepressed solvent extracted, low erucic acid, low glucosinolates	5-06-145	93	38.0	2.32	1.88	1.67	1.07	1.51	2.65	2.45	0.68	0.47	1.52	0.93	1.71	0.44	1.94
	CASEIN																	
12	dehydrated	5-01-162	93	87.2	3.61	1.79	5.81	2.78	4.82	9.00	7.99	2.65	0.21	4.96	5.37	4.29	1.05	6.46
13	precipitated dehydrated	5-20-837	92	85.0	3.42	1.81	5.52	2.52	4.77	8.62	7.31	2.80	0.15	4.81	5.17	4.00	0.98	5.82
	CORN, DENT YELLOW *Zea mays indentata*																	
14	distillers grains, dehydrated	5-28-235	94	27.9	0.97	0.49	0.70	0.62	0.99	3.01	0.78	0.40	0.24	0.94	0.84	0.49	0.20	1.18
15	distillers grains with solubles, dehydrated	5-28-236	93	27.2	0.98	0.57	1.61	0.66	1.00	2.20	0.75	0.60	0.40	1.20	0.74	0.92	0.19	1.30
16	distillers solubles, dehydrated	5-28-237	92	28.5	1.05	1.10	1.30	0.70	1.25	2.11	0.90	0.50	0.40	1.30	0.95	1.00	0.30	1.39
17	gluten, meal, 60% protein	5-28-242	90	62.0	1.93	1.64	3.07	1.22	2.29	10.11	1.00	1.91	1.11	3.77	2.94	1.97	0.25	2.74
18	gluten with bran (corn gluten feed)	5-28-243	90	22.0	1.01	0.99	0.80	0.71	0.65	1.89	0.63	0.45	0.51	0.77	0.58	0.89	0.10	0.05
19	grain	4-02-935	89	8.8	0.50	0.37	0.40	0.20	0.37	1.10	0.24	0.20	0.15	0.47	0.45	0.39	0.09	0.52
20	grits by-product (Hominy feed)	4-03-011	90	10.0	0.47	0.40	0.50	0.20	0.40	0.84	0.40	0.13	0.13	0.35	0.49	0.40	0.10	0.49

	COTTON *Gossypium* spp																	
21	seeds, meal mechanically extracted, 41% protein (expeller)	5-01-617	93	40.9	4.26	2.28	1.70	1.08	1.57	2.47	1.51	0.55	0.59	2.17	0.69	1.38	0.55	1.97
22	seeds, meal prepressed solvent extracted, 41% protein	5-07-872	90	41.4	4.59	1.70	1.80	1.10	1.33	2.41	1.71	0.52	0.64	2.22	1.02	1.32	0.47	1.89
23	seeds, meal prepressed solvent extracted, 44% protein	5-07-873	91	44.7	4.77	1.80	2.17	1.48	1.36	2.44	1.73	0.61	1.12	1.55	1.45	1.49	0.55	1.91
	FISH																	
24	solubles, condensed	5-01-969	51	31.5	1.61	3.41	0.83	1.56	1.06	1.86	1.73	0.50	0.30	0.93	0.40	0.86	0.31	1.16
25	solubles, dehydrated	5-01-971	92	63.6	2.78	5.89	2.02	2.18	1.95	3.16	3.28	1.00	0.66	1.48	0.78	1.35	0.51	2.22
	FISH, ANCHOVY *Engraulis ringen*																	
26	meal mechanically extracted	5-01-985	92	64.2	3.66	3.59	2.32	1.53	3.01	4.83	4.90	1.93	0.59	2.70	2.18	2.68	0.74	3.38
	FISH, HERRING *Clupea harengus*																	
27	meal mechanically extracted	5-02-000	93	72.3	4.84	4.61	2.73	1.70	3.22	5.34	5.70	2.10	0.72	2.79	2.27	3.00	0.81	4.38
	FISH, MENHADEN *Brevoortia tyrannus*																	
28	meal mechanically extracted	5-02-009	92	60.5	3.79	4.19	2.25	1.46	2.85	4.50	4.83	1.78	0.56	2.48	1.98	2.50	0.68	3.23
	FISH, WHITE Gadidae (family)-Lophiidae (family)-Rajidae (family)																	
29	meal mechanically extracted	5-02-025	91	62.2	4.02	4.42	3.06	1.34	2.72	4.36	4.53	1.68	0.75	2.28	1.83	2.57	0.67	3.02
	GELATIN																	
30	process residue (gelatin by-products)	5-14-503	91	88.0	7.40	20.00	2.80	0.85	1.40	3.10	3.70	0.68	0.09	1.70	0.26	1.30	0.09	1.80
	HOMINY FEED—SEE CORN																	
	LIVERS																	
31	meal	5-00-389	92	65.6	4.14	5.57	2.49	1.47	3.09	5.28	4.80	1.22	0.89	2.89	1.69	2.48	0.59	4.13
	MEAT																	
32	meal rendered	5-00-385	92	54.4	3.73	6.30	1.60	1.30	1.60	3.32	3.00	0.75	0.66	1.70	0.84	1.74	0.36	2.30
33	with bone, meal rendered	5-00-388	93	50.4	3.62	6.79	1.85	0.90	1.40	2.80	2.60	0.65	0.25	1.50	0.76	1.50	0.28	2.00
	MILLET, PEARL *Pennisetum glaucum*																	
34	grain	4-03-118	90	15.7	0.74	0.47	0.74	0.31	0.37	1.14	0.45	0.25	0.24	0.56	0.35	0.48	0.08	0.49
	MILLET, PROSO *Panicum miliaceum*																	
35	grain	4-03-120	90	11.6	0.36	—	—	0.21	0.45	1.15	0.26	0.29	—	0.57	—	0.40	0.17	0.58
	OATS *Avena sativa*																	
36	grain	4-03-309	89	11.4	0.79	0.50	0.40	0.24	0.52	0.89	0.50	0.18	0.22	0.59	0.53	0.43	0.16	0.68
37	grain, pacific coast	4-07-999	91	9.0	0.60	0.40	0.30	0.10	0.40	0.30	0.40	0.13	0.17	0.44	0.20	0.20	0.12	0.51
38	hulls	1-03-281	92	4.6	0.14	0.14	0.14	0.07	0.14	0.25	0.14	0.07	0.06	0.13	0.14	0.13	0.07	0.20
	PEA *Pisum* spp																	
39	seeds	5-03-600	90	23.8	1.40	1.10	—	0.72	1.10	1.80	1.60	0.31	0.17	1.30	—	0.94	0.24	1.30
	PEANUT *Arachis hypogaea*																	
40	kernels, meal mechanically extracted (peanut meal) (expeller)	5-03-649	90	39.8	5.40	2.20	1.30	1.10	1.80	3.40	1.60	0.45	0.70	2.60	1.61	1.40	0.50	2.40
41	kernels, meal solvent extracted (peanut meal)	5-03-650	93	50.7	5.50	2.70	2.22	1.19	2.10	2.99	1.76	0.44	0.76	2.75	2.00	1.45	0.65	1.82

TABLE 25 Amino Acid Composition of Some Feeds Commonly Used for Poultry; Data on As-Fed Basis—*Continued*

Entry Number	Feed Name Description	International Feed Number[a]	Dry Matter (%)	Protein (%)	Arginine (%)	Glycine (%)	Serine (%)	Histidine (%)	Isoleucine (%)	Leucine (%)	Lysine (%)	Methionine (%)	Cystine (%)	Phenylalanine (%)	Tyrosine (%)	Threonine (%)	Tryptophan (%)	Valine (%)
	POULTRY																	
42	by-product, meal rendered (Viscera with feet and heads)	5-03-798	93	58.0	4.00	5.90	3.68	1.50	2.00	3.70	2.70	1.00	0.69	2.10	0.54	2.00	0.53	2.60
43	feathers, meal hydrolyzed	5-03-795	93	86.4	5.42	6.31	9.26	0.34	3.26	6.72	1.67	0.42	4.00	3.26	6.31	3.43	0.50	5.57
	RICE *Oryza sativa*																	
44	bran with germ (Rice bran)	4-03-928	91	12.9	0.89	0.80	0.32	0.33	0.52	0.90	0.59	0.20	0.10	0.58	0.68	0.48	0.15	0.75
45	grain, polished and broken (Brewers rice)	4-03-932	89	8.7	0.62	0.63	1.36	0.17	0.35	0.52	0.24	0.15	0.08	0.36	0.41	0.29	0.13	0.50
46	polishings	4-03-943	90	12.2	0.78	0.71	1.36	0.24	0.41	0.80	0.57	0.22	0.10	0.46	0.63	0.40	0.13	0.76
	RYE *Secale cereale*																	
47	grain	4-04-047	88	12.1	0.53	0.49	0.52	0.26	0.47	0.70	0.42	0.17	0.19	0.56	0.26	0.36	0.11	0.56
	SAFFLOWER *Carthamus tinctorius*																	
48	seeds, meal solvent extracted	5-04-110	92	23.4	1.95	1.13	—	—	0.28	—	0.72	0.34	0.36	—	—	0.51	0.27	—
49	seeds without hulls, meal solvent extracted	5-07-959	92	43.0	3.65	2.32	—	1.07	1.56	2.46	1.27	0.68	0.70	1.75	1.07	1.30	0.59	2.33
	SESAME *Sesamum indicum*																	
50	seeds, meal mechanically extracted	5-04-220	93	43.8	4.93	4.22	2.96	1.09	2.12	3.33	1.30	1.20	0.59	2.22	2.00	1.65	0.80	2.41
	SORGHUM *Sorghum bicolor*																	
51	grain, 8–10% protein	4-20-893	87	8.8	0.34	0.35	0.39	0.19	0.42	1.18	0.21	0.16	0.16	0.42	0.38	0.29	0.10	0.53
52	grain, more than 10% protein	4-20-894	88	11.0	0.35	0.32	0.45	0.23	0.43	1.37	0.22	0.15	0.11	0.52	0.17	0.33	0.09	0.54
	SOYBEAN *Glycine max*																	
53	flour by-product (Soybean mill feed)	4-04-594	89	13.3	0.94	0.40	—	0.18	0.40	0.57	0.48	0.10	0.21	0.37	0.23	0.30	0.10	0.37
54	protein concentrate, more than 70% protein	5-08-038	93	84.1	6.70	3.30	5.30	2.10	4.60	6.60	5.50	0.81	0.49	4.30	3.10	3.30	0.81	4.40

55	seeds, heat processed	5-04-597	90	37.0	2.80	2.00	2.17	0.89	2.00	2.80	2.40	0.51	0.64	1.80	1.20	1.50	0.55	1.80
56	seeds, meal solvent extracted	5-04-604	89	44.0	3.28	2.29	2.45	1.15	2.39	3.52	2.93	0.65	0.69	2.27	1.28	1.81	0.62	2.34
57	seeds without hulls, meal solvent extracted	5-04-612	90	48.5	3.68	2.29	2.89	1.32	2.57	3.82	3.18	0.72	0.73	2.11	2.01	1.91	0.67	2.72
	SUNFLOWER, COMMON *Helianthus annuus*																	
58	seeds, meal solvent extracted	5-09-340	90	23.3	2.30	—	1.00	0.55	1.00	1.60	1.00	0.50	0.50	1.15	—	1.05	0.45	1.60
59	seeds without hulls, meal solvent extracted	5-04-739	93	45.4	3.50	2.69	1.75	1.39	2.78	3.88	1.70	0.72	0.71	2.93	1.19	2.13	0.71	3.24
	TRITICALE *Triticale hexaploide*																	
60	grain	4-20-362	90	15.8	0.86	0.70	0.76	0.40	0.61	1.18	0.52	0.21	0.29	0.80	0.51	0.57	0.18	0.84
	WHEAT *Triticum aestivum*																	
61	bran	4-05-190	90	15.7	0.98	0.90	0.90	0.34	0.59	0.91	0.59	0.17	0.25	0.49	0.40	0.42	0.30	0.73
62	flour by-product, less than 4% fiber (wheat red dog)	4-05-203	88	15.3	0.96	0.74	0.75	0.41	0.55	1.06	0.59	0.23	0.37	0.66	0.46	0.50	0.19	0.72
63	flour by-product, less than 9.5% fiber (wheat middlings)	4-05-205	88	16.0	1.15	0.63	0.75	0.37	0.58	1.07	0.69	0.21	0.32	0.64	0.45	0.49	0.20	0.71
64	flour by-product, less than 7% fiber (wheat shorts)	4-05-201	88	16.5	1.18	0.96	0.77	0.45	0.58	1.09	0.79	0.27	0.36	0.67	0.47	0.60	0.21	0.83
65	grain, hard red winter	4-05-268	87	14.1	0.58	0.72	0.63	0.22	0.58	0.94	0.40	0.19	0.26	0.71	0.43	0.37	0.18	0.63
66	grain, soft white winter	4-05-337	89	10.2	0.40	0.49	0.55	0.20	0.42	0.59	0.31	0.15	0.22	0.45	0.39	0.32	0.12	0.44
	WHEY *Bos taurus*																	
67	dehydrated	4-01-182	93	12.0	0.34	0.30	0.32	0.18	0.82	1.19	0.97	0.19	0.30	0.33	0.25	0.89	0.19	0.68
68	low lactose, dehydrated (dried whey product)	4-01-186	91	15.5	0.67	1.04	0.76	0.10	0.90	1.15	1.47	0.57	0.57	0.50	0.20	0.50	0.18	0.30
	YEAST, BREWERS *Saccharomyces cerevisiae*																	
69	dehydrated	7-05-527	93	44.4	2.19	2.09	—	1.07	2.14	3.19	3.23	0.70	0.50	1.81	1.49	2.06	0.49	2.32
	YEAST, TORULA *Torulopsis utilis*																	
70	dehydrated	7-05-534	93	47.2	2.60	2.60	2.76	1.40	2.90	3.50	3.80	0.80	0.60	3.00	2.10	2.60	0.50	2.90

[a]First digit is class of feed: 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; the other five digits are the International Feed Number.

TABLE 26 Average Fatty Acid Composition of Some Feeds Commonly Used for Poultry[a]; Data on As-Fed Basis

Entry Number	Feed Name Description	International Feed Number	Dry Matter (%)	Ether Extract (%)	Selected Fatty Acids, % of Feed							
					$C_{12:0}$	$C_{14:0}$	$C_{16:0}$	$C_{16:1}$	$C_{18:0}$	$C_{18:1}$	$C_{18:2}$	$C_{18:3}$
01	Alfalfa, meal dehydrated, 17% protein	1-00-023	92	2.0	0.01	0.01	0.57	0.05	0.08	0.13	0.37	0.78
02	Barley, grain	5-00-549	89	1.8	0.01	—	0.49	0.02	0.03	0.37	0.78	0.08
03	Corn, dent yellow, distillers solubles, dehydrated	5-28-237	92	9.0	—	—	1.80	0.07	0.09	2.25	4.77	0.02
04	Corn, dent yellow, grain	4-02-935	89	3.8	—	—	0.62	—	0.10	1.17	1.82	0.09
05	Corn, dent yellow, grits by-product (hominy feed)	4-03-011	90	6.9	—	—	0.97	—	0.14	1.94	3.75	0.10
06	Corn, dent yellow, gluten, meal	5-28-241	90	2.5	—	—	0.50	—	0.06	0.61	1.16	—
07	Cotton, seeds, meal solvent extracted, 41% protein	5-01-621	93	3.9	—	0.02	1.22	—	0.02	0.53	2.46	0.03
08	Fish, menhaden, meal mechanically extracted	5-02-009	92	9.4	0.01	1.15	3.61	1.58	0.57	1.96	0.14	0.08
09	Meat with bone, meal rendered	5-00-388	93	8.6	—	0.22	2.36	0.44	1.42	3.74	0.31	—
10	Oats, grain	4-03-309	89	4.2	—	0.05	0.93	0.04	0.05	1.60	1.47	0.09
11	Peanut, kernels, meal mechanically extracted (expeller)	5-03-649	90	7.3	—	—	1.52	0.08	0.23	3.32	1.43	—
12	Poultry, feathers, meal hydrolyzed	5-03-795	93	3.3	0.01	0.06	0.99	0.19	0.48	0.98	0.43	—
13	Sorghum, milo, grain	4-04-444	89	2.8	—	—	0.56	0.15	0.03	0.89	1.13	0.06
14	Soybean, seeds without hulls, meal solvent extracted	5-04-612	90	1.0	—	—	0.24	0.01	0.05	0.16	0.47	0.07
15	Wheat, grain	5-05-211	87	1.9	—	—	0.46	0.08	0.03	0.44	0.81	0.11
16	Wheat, middlings	4-05-205	88	3.0	—	—	0.61	—	—	0.58	1.70	0.12

[a] Fatty acid composition data obtained from Edwards (1964).

essential amino acids in protein increase, but, in other instances, they decrease. For example, there is a marked inverse relationship between the protein content of wheat or grain sorghum and lysine concentration in the protein. As protein content increases, lysine in the protein decreases.

This relationship is most prominent within cultivars of wheat and grain sorghum and is the result of a shift among the major proteins within these grains, whereby the proportion of prolamine (low in lysine) increases at the expense of other proteins high in lysine. Certain other essential amino acids (arginine, methionine, and cystine) may be affected similarly. An inverse relationship between protein content and concentration of certain essential amino acids in the protein also has been reported for cultivars of barley, corn, oats, and rice. The alterations in amino acid composition with increasing protein concentration generally are less with these grains than those observed for wheat and milo.

Recently, much research has been focused on the selection of cultivars of grains in which the concentrations of both protein and selected amino acids within the protein may be increased. Examples include high-lysine corn and high-protein barley. The quantities of these grains available for feeding to poultry are limited at the present time.

PROTEIN SUPPLEMENTS

A number of the feedstuffs used to supply supplementary protein (see also pp. 4–5) to poultry diets may contain naturally occurring toxic or potentially toxic compounds.

Cottonseed meal, for example, may contain gossypol pigments. The amount of gossypol present in cottonseed meal is variable and depends upon the strain of seed and manufacturing procedures. Gossypol adversely affects the bird, with younger birds being less tolerant than older birds. Hens consuming gossypol lay eggs with olive-discolored yolks. The discoloration may be evident in the newly laid egg but more often after storage. Cottonseed meals and oil may also cause development of a pinkish color in egg whites caused by the presence of cycloproprenoid fatty acids.

Rapeseed meals manufactured from many varieties of rapeseed contain goitrogenic, or progoitrogenic, compounds (glucosinolates) at sufficiently high concentra-

TABLE 27 Fatty Acid Composition and Metabolizable Energy of Selected Fats[a], Oils, and Carbohydrates; Data on As-Fed Basis

Entry Number	Feed Name Description	International Feed Number	Ether Extract (%)	Selected Fatty Acids, % of the Fat										ME (kcal/kg)
				$C_{8:0}$	$C_{10:0}$	$C_{12:0}$	$C_{14:0}$	$C_{16:0}$	$C_{16:1}$	$C_{18:0}$	$C_{18:1}$	$C_{18:2}$	$C_{18:3}$	
01	Animal-poultry, fat[b]	4-00-409	100	—	—	0.1	1.6	19.9	2.8	13.7	46.4	11.8	1.0	7,800–8,700[c]
02	Animal, tallow	4-08-127	100	—	—	0.9	3.7	24.9	4.2	18.9	36.0	3.1	0.6	7,100–8,500[c]
03	Animal-vegetable, fat, blended[b]	4-28-210	100	1.0	0.9	6.6	3.1	16.5	2.8	11.9	30.2	20.6	2.6	8,100–8,800[c]
04	Canola, oil	4-06-144	100	—	—	—	—	4.8	0.5	1.6	53.8	22.1	11.1	8,800
05	Coconut, oil	4-09-320	100	7.5	6.0	44.6	16.8	8.2	—	2.8	5.8	1.8	—	—
06	Corn, oil	4-07-882	100	—	—	—	—	10.9	—	1.8	24.2	58.0	0.7	8,800
07	Cottonseed, oil	4-20-836	100	—	—	—	0.8	22.7	0.8	2.3	17.0	51.5	0.2	8,800
08	Palm, oil	4-26-228	100	—	—	0.1	1.0	43.5	0.3	4.3	36.6	9.1	0.2	8,300
09	Peanut, oil	4-03-658	100	—	—	—	0.1	9.5	0.1	2.2	44.8	32.0	—	8,800
10	Poultry, fat	4-09-319	100	—	—	0.1	0.9	21.6	5.7	6.0	37.3	19.5	1.0	8,200
11	Safflower, oil	4-20-526	100	—	—	—	0.1	6.2	0.4	2.2	11.7	74.1	0.4	8,800
12	Soybean, oil	4-07-983	100	—	—	—	0.1	10.3	0.2	3.8	22.8	51.0	6.8	8,800
13	Sunflower, oil	4-20-833	100	—	—	—	—	5.9	—	4.5	19.5	65.7	—	8,800
14	Corn, starch[d]	4-02-889	0.1											3,650
15	Glucose[d]	4-02-125	0.0											3,630
16	Sucrose[d]	4-04-701	0.0											3,680

[a]Feed grade fats and oils usually contain water and other nonfat materials; adjustments in fatty acid and ME concentrations should be made accordingly.

[b]Examples of animal-poultry fat and animal-vegetable fat-blends offered in commerce. There is considerable variation in composition in animal-vegetable fat sources and blends.

[c]Subject to variation related to ingredient composition of diets, level of fat inclusion in diet, and age of poultry (see p. 6).

[d]On dry matter basis.

TABLE 28 Nitrogen Concentration, Crude Protein Equivalents, and Metabolizable Energy Values for Amino Acids

Amino Acid	Nitrogen (%)	Crude Protein Equivalent (g/100 g) of Amino Acid	Metabolizable Energy (kcal/kg)[a]
Alanine	15.72	98.25	3,060
Arginine	32.16	201.00	2,940
Asparagine	21.20	132.50	1,760
Aspartic acid	10.52	65.75	2,020
Cystine	11.66	72.88	2,060
Glutamic acid	9.52	59.50	2,880
Glutamine	19.17	119.81	2,630
Glycine	18.66	116.62	1,570
Histidine	27.08	169.25	
Isoleucine	10.68	66.75	5,650
Leucine	10.67	66.69	5,640
Lysine	19.16	119.75	4,600
Methionine	9.39	58.69	3,680
Phenylalanine	8.48	53.00	6,030
Proline	12.17	76.06	3,980
Serine	13.33	83.31	2,210
Threonine	11.76	73.50	3,150
Tryptophan	13.72	85.75	5,460
Tyrosine	7.73	48.31	5,240
Valine	11.96	74.75	4,990

[a]Assuming 100 percent digestibility and conversion of nitrogen to uric acid (including urea in the case of arginine).

tions to reduce growth rate and egg production when fed to poultry. Canadian plant geneticists have been successful in developing rapeseed cultivars, called canola, that contain negligible quantities of glucosinolates in the seed. Meals manufactured from these cultivars are called *canola meal* and are characterized by negligible concentrations of glucosinolates.

Soybeans contain compounds that inhibit the activity of the proteolytic enzyme trypsin. Ingestion of the antitryptic substances induces enlargement of the pancreas. The trypsin inhibitor is inactivated by heat-treatment of soybean meal. The heat-treatment must be carefully controlled because overheating can result in deterioration of protein quality.

Animal protein sources, *meatmeals*, *fish meals*, *blood meal*, and *feather meal*, are subject to variation as a result of manufacturing conditions and the nature of the raw material from which they are processed. Severe heating during drying will lower digestibility and cause some loss of essential amino acids. Proteins from hide, scales, feathers, and hair have low digestibility and high concentrations of collagenous protein. The latter will result in relatively low concentrations of tryptophan in the product.

MYCOTOXINS

These highly toxic metabolites of molds are of great concern as contaminants of feedstuffs. A number of these poisonous compounds may be present in moldy feed. The one that appears to occur most frequently is aflatoxin. Among species and classes of poultry the duckling is the most sensitive, whereas the mature Japanese quail is fairly resistant. Aflatoxin reduces growth rate, egg production, and hatchability. It has been demonstrated to increase susceptibility to disease in chickens and turkeys by interfering with the immune response. Aflatoxin has been implicated in the fatty liver syndrome in layers, in hemorrhagic disease in broilers and turkey poults, and in failure to absorb nutrients, particularly fat.

The presence of aflatoxin, or other mycotoxins, should always be suspected in lots of moldy grain or other feedstuffs. Because of the high toxicity of these compounds, the use of moldy feeds in poultry diets, even in small amounts, involves considerable risk.

TABLE 29 Element Concentrations in Common Mineral Sources; Data As-Fed Basis[a]

Entry Number	Feed Name Description	International Feed Number	Calcium (%)	Phosphorus (%)	Sodium (%)	Potassium (%)	Magnesium (%)	Chlorine (%)	Fluorine (%)	Sulfur (%)	Iron (mg/kg)	Copper (mg/kg)	Manganese (mg/kg)	Zinc (mg/kg)
01	Bone, meal steamed	6-00-400	29.8	12.5	0.04	0.2	0.3	—	—	2.4	5,000	—	—	100
02	Calcium carbonate, $CaCO_3$	6-01-069	38.0	0.0	0.02	0.06	0.05	—	0.00	—	300	—	300	—
03	Calcium phosphate, dibasic from defluorinated phosphoric acid	6-01-080	21.3	18.7	0.06	0.1	0.6	0.013	0.18	1.11	14,000	10	300	100
04	Calcium phosphate, mono-dibasic	6-26-137	16.0	21.0	0.06	0.07	0.6	—	0.15	1.2	12,500	42	300	160
05	Calcium sulfate, dihydrate, $CaSO_4 \cdot 2H_2O$	6-01-090	22.6	—	—	—	—	—	—	18.1	—	—	—	—
06	Limestone, ground	6-02-632	38.0	—	0.05	0.1	2.1	0.03	<0.0025	—	3,500	—	—	—
07	Magnesium oxide, MgO	6-02-756	3.0	0.03	0.015	0.02	55.0	0.02	0.06	0.04	6,000	10	150	10
08	Meat with bone, meal rendered	5-00-388	10.3	5.1	0.7	1.3	1.0	0.7	—	0.2	700	2	13	90
09	Oyster, shells, ground	6-03-481	38.0	0.1	0.2	0.1	0.3	0.01	—	—	2,900	—	100	—
11	Phosphate, defluorinated	6-01-780	32.0	18.0	4.9	0.1	0.4	—	0.18	—	6,700	20	200	60
10	Phosphate, rock, curacao, ground	6-05-586	36.0	14.0	0.3	—	0.8	—	0.53	—	3,500	—	—	—
12	Phosphate, rock, soft	6-03-947	17.5	9.5	0.15	0.30	0.35	0.007	1.25	0.31	17,000	64	39	90
13	Potassium chloride, KCl	6-03-755	0.05	—	1.0	50.5	0.34	47.3	—	0.45	600	7	7	9
14	Potassium and magnesium sulfate	6-06-177	0.06	—	0.76	18.5	11.6	1.25	0.001	22.3	100	2	20	9
15	Potassium sulfate, K_2SO_4	6-08-098	0.15	—	0.09	41.0	0.6	1.5	—	17.9	700	—	10	—
16	Sodium carbonate, Na_2CO_3	6-12-316	—	—	43.39	—	—	—	—	—	—	—	—	—
17	Sodium bicarbonate, $NaHCO_3$	6-04-272	—	—	27.0	—	—	—	—	—	—	—	—	—
18	Sodium chloride, NaCl (common salt)	6-04-152	0.3	—	39.0	—	0.005	60.0	—	0.2	50	—	—	—
19	Sodium phosphate, dibasic, from furnaced phosphoric acid, Na_2HPO_4	6-04-286	—	20.8	31.0	—	—	—	—	—	—	—	—	—
20	Sodium phosphate, monobasic $NaH_2PO_4 \cdot H_2O$	6-04-288	—	25.8	19.1	—	—	—	—	—	—	—	—	—
21	Sodium sulfate, decahydrate, $Na_2SO_4 \cdot 10H_2O$	6-04-291	—	—	13.8	—	—	—	—	9.7	—	—	—	—
22	Phosphoric acid, H_3PO_4	6-03-707	0.08	23.7	0.05	—	0.45	—	0.19	1.1	12,000	10	—	—

[a]The mineral supplements used as feed supplements are not chemically pure compounds. They usually contain small amounts of a variety of other minerals. Use the supplier's analysis if it is available.

11 Standard Reference Diets for Chicks

Many laboratories using chicks for studies in microbiology, physiology, pathology, behavior, toxicology, and biochemistry need a nutritionally complete standard or reference diet. The diets shown in Table 30 have been used successfully in various laboratories and are presented as guides to those requiring such formulations.

Vitamin and trace mineral concentrations in the diets are above requirements. There is, therefore, considerable allowance for storage losses of unstable vitamins and variations in the composition of natural ingredients.

The diets are not intended to promote maximum growth.

TABLE 30 Formulas for Three Types of Reference Diets for Chicks

Ingredient	Practical Diet[a]	Purified Diet[b]	Chemically Defined Diet[c]
Ground yellow corn (8.8% protein) (g/kg)	580	—	—
Soybean meal (48.5% protein) (g/kg)	350	—	—
Isolated soybean protein (g/kg)	—	250	—
DL-Methionine (g/kg)	2.5	6	—
Glycine (g/kg)	—	4	—
Crystalline amino acids (g/kg)	—	—	204.8[d]
Corn oil (g/kg)	30	40	50–150
Glucose or starch (g/kg)	to 1 kg	to 1 kg	to 1 kg
Cellulose (g/kg)	—	30	30
Choline chloride (50%) (g/kg)	1.5	2.0	2.0
Thiamin HCl (mg/kg)	1.8	15.0	100.0
Riboflavin (mg/kg)	3.6	15.0	16.0
Calcium pantothenate (mg/kg)	10.0	20.0	20.0
Niacin (mg/kg)	25.0	50.0	100.0
Pyridoxine HCl (mg/kg)	3.0	6.0	6.0
Folacin (mg/kg)	0.55	6.0	4.0
Biotin (mg/kg)	0.15	0.6	0.6
Vitamin B_{12} (mg/kg)	0.01	0.02	0.02
Inositol (mg/kg)	—	—	100.0
Para-aminobenzoic acid (mg/kg)	—	—	2.0
Ascorbic acid (mg/kg)	—	—	250.0
Vitamin A (IU/kg)	1,500	4,500	10,000
Vitamin D_3 (ICU/kg)	400	4,500	600
Vitamin E (IU/kg)	10	50	20
Vitamin K[e] (mg/kg)	0.55	1.5	5.0
Antioxidant[f] (mg/kg)	125	100	125
Iodized salt (g/kg)	5	—	—
NaCl (g/kg)	—	6	8.8
$CaCO_3$ (g/kg)	10	14.8	3
$CaHPO_4 \cdot 2H_2O$ (g/kg)	20	20.7	—
$Ca_3(PO_4)_2$ (g/kg)	—	—	28
$MgSO_4 \cdot 7H_2O$ (g/kg)	—	6	3.5
K_2HPO_4 (g/kg)	—	10	9
$NaHCO_3$ (g/kg)	—	—	15
KCl (g/kg)	—	1	—
$MnSO_4 \cdot ca5H_2O$ (mg/kg)	170	350	650
$ZnSO_4 \cdot H_2O$ (mg/kg)	110	—	—
$ZnCO_3$ (mg/kg)	—	150	100
$Fe_2(SO_4)_3 \cdot 7H_2O$ (mg/kg)	—	500	—
Ferric citrate · $ca5H_2O$ (mg/kg)	500	—	500
$CuSO_4 \cdot 5H_2O$ (mg/kg)	16	30	20
Na_2SeO_3 (mg/kg)	0.2	0.2	0.2
KI (mg/kg)	—	—	40
KIO_4 (mg/kg)	—	2	—
$CoCl_2$ (mg/kg)	—	1.7	—
$CoSO_4 \cdot 7H_2O$ (mg/kg)	—	—	1
H_3BO_3 (mg/kg)	—	—	9
$Na_2MoO_4 \cdot 2H_2O$ (mg/kg)	—	—	9

[a]Animal Nutrition Research Council Reference chick diet.

[b]Scott, M. L., M. C. Nesheim, and R. J. Young. 1982. *Nutrition of the Chicken*. 3rd ed. M. L. Scott and Assoc. Ithaca, N.Y. pp. 545–546.

[c]Baker, D. H., K. R. Robbins, and J. S. Buck. 1979. Modification of the level of histidine and sodium bicarbonate in the Illinois crystalline amino acid diet. *Poult. Sci.* 58:749–750.

[d]11.5 g L-arginine HCl, 4.5 g L-histidine HCl · H_2O, 11.4 g L-lysine HCl, 4.5 g L-tyrosine, 1.5 g L-tryptophan, 5.0 g L-phenylalanine, 3.5 g DL-methionine, 3.5 g L-cystine, 6.5 g L-threonine, 10.0 g L-leucine, 6.0 g L-isoleucine, 6.9 g L-valine, 6 g glycine, 4.0 g L-proline, 120.0 g L-glutamic acid.

[e]See p. 27.

[f]See p. 9.

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Conversion Factors—Weights and Measures

Units	Multiplied by the Factor Below Equals	Units	Multiplied by the Factor Below Equals	Units
lb	453.6	g	0.002205	lb
lb	0.4536	kg	2.205	lb
oz	28.35	g	0.035273	oz
kg	1,000	g	0.001	kg
kg	1,000,000	mg	0.000001	kg
g	1,000	mg	0.001	g
g	1,000,000	mcg (or μg)	0.000001	g
g	10^9	ng (nanogram)	10^{-9}	g
g	10^{12}	pg (picogram)	10^{-12}	g
mg	1,000	mcg (or μg)	.001	mg
mg/kg[a]	0.0001	%	10,000	mg/kg
ppm	0.0001	%	10,000	ppm
gal (U.S.)	3.785	1	0.2642	gal (U.S.)
gal (Brit.)	4.546	1	0.220	gal (Brit.)
bu (bushel)	0.3525	hl (hectoliter)	2.837	bu
cal (calorie)	4.184	j (joule)	0.239	cal
kcal (kilocalorie)	1,000	cal	0.001	kcal
Mcal (megacalorie)	1,000,000	cal	0.000001	Mcal
Mcal	1,000	kcal	0.001	Mcal

[a]100 ppm = 100 mg/kg = 0.010%,
thus converting 0.0002% = 2 ppm = 2 mg/kg.

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