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NUTRIENT REQUIREMENTS OF DOMESTIC ANIMALS

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NUTRIENT REQUIREMENTS OF
DOMESTIC ANIMALS

Number 1

Nutrient Requirements of Poultry

Fifth Revised Edition, 1966

A Report of the
SUBCOMMITTEE ON POULTRY NUTRITION
COMMITTEE ON ANIMAL NUTRITION
AGRICULTURAL BOARD
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FOREWORD

This report on the *Nutrient Requirements of Poultry* has been prepared by the Subcommittee on Poultry Nutrition of the Committee on Animal Nutrition, National Academy of Sciences—National Research Council. It is the fifth revision of the original report, which was published in June, 1944. The members of the subcommittee are specialists in poultry nutrition and are actively engaged in poultry-nutrition research.

In revising the report, all new information on the quantitative nutrient requirements of poultry, published since the fourth revision was issued in 1960, was taken into consideration. Thus standards of the greatest possible reliability in view of the available evidence have been developed and are presented in this report.

The values presented in this report are not final. Whenever new experimental evidence is obtained, the nutrient requirements presented here will be revised and enlarged by the subcommittee to bring them up to date.

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INTRODUCTION

The Subcommittee on Poultry Nutrition of the National Academy of Sciences—National Research Council's Committee on Animal Nutrition was appointed in 1943 and charged with preparing nutrient-requirement standards for poultry. The first report of the Subcommittee was published by the Academy Research Council in 1944. This has been revised at various times to take advantage of new findings of practical worth. The first revision of the tables of nutrient requirements was published in 1946, a second in 1950, a third in 1954, and a fourth in 1960.

Since 1960 new data have become available which necessitated revising the tables for a fifth time. In addition, valuable suggestions for improving the clarity, and thus enhancing the usefulness, of the tables have been received from persons working in the experiment stations and the commercial feed industry. The Subcommittee has attempted to incorporate these suggestions into the revised edition of the report.

The same general procedures were followed in making this revision as were used in compiling the original publication. The Subcommittee has evaluated the new data, keeping in mind the data on which the original recommended allowances were based. Revised requirements listed in tables in this report are not to be considered as final. They will be revised further as new information on the quantitative requirements of poultry becomes available.

Nutrient requirements of chickens, turkeys, ducks, pheasants, and quail are given in Tables 1 to 5. Values given in these tables are based on the results of experimental work. Where several comparable experiments were available for consideration by the Subcommittee, the values in the tables represent approximate averages of the results.

Research workers conducting experimental work on the nutritive requirements of animals normally base their conclusions on the performance of groups of animals. Where performance is determined on the basis of gains in weight or feed efficiency, averages usually provide the basis for interpreting experimental work. Where deficiency symptoms are the criteria for determining nutrient adequacy or inadequacy, freedom from the deficiency syndrome of all animals in experimental groups is usually the basis of investigators' conclusions.

To make use of results of this character in preparing the tables in this report, some calculations and interpolations were necessarily employed. Values have not been increased by any intentionally added amounts since the nature of the original findings indicate that they represent valid requirements for the maintenance of normal health and productivity of animals.

In practical feed formulation, it is often desirable to include margins of safety to compensate for possible losses of vitamins during feed processing, transportation, and storage, and for variations in feed composition and in the environment. Individual feed manufacturers can best evaluate their own situations and determine margins most suitable to their specific conditions.

It has been customary for research workers in poultry nutrition to express nutrient requirements in terms of concentration of nutrient-per-unit-weight of ration; this method has been followed in the present report. This convenient method is somewhat inaccurate because the nutrient intake of an animal is thus made subject to the absolute level of feed consumption, which in turn is dependent mainly on the energy concentration in the ration.

Protein and amino-acid requirements are particularly subject to this effect, because they represent more nearly the fixed quantities required per day at a given stage of growth or production, rather than percentages of the ration. In its simplest terms, the protein requirement bears a fairly constant relation to the energy concentration of the ration, dependent on the stage of life. That this is true in principle has been shown experimentally in several laboratories. However, even this means of expressing protein requirement does not lead to fixed values, apparently because of protein-sparing effects of particular carbohydrate and fat combinations and other, more obscure, differences between rations.

Relative concentrations of protein and energy in the ration also have an important effect on the fat content of the body. In relative protein deficiency with *ad libitum* feeding, fat deposition is markedly increased. With higher protein levels relative to energy content, less fat is deposited. Increasing protein level above that required for maximum growth rate reduces fat deposition still further.

It is evident, therefore, that the protein requirement can be defined accurately only in relation to energy concentration, degree of fat deposition, and a limited range of nutrient combinations, using those purified and practical feedstuffs that have been subjected to experimental study. For practical purposes in farm operations and feed manufacturing, sufficient work has been done with growing chicks to define, with reasonable accuracy, the minimum protein requirement for maximum growth rate in relation to energy level. Similar estimates can be made from more limited data for laying hens and growing turkeys.

Protein levels shown in Table 1 for chickens will meet the approximate minimum requirements for growth in rations containing 2,750 kcal of metabolizable energy per kg and for egg production in rations containing 2,850 kcal per kg.

Protein levels shown in Table 2 for turkeys will meet the approximate minimum requirements for early growth in a ration containing 2,450 kcal of metabolizable energy per kg, and for later growth at an energy level of 2,600 kcal per kg.

When energy concentrations are used that are materially different from those on which the tables are based, proportionate changes in protein level will be necessary to maintain protein adequacy. The estimates apply primarily to rations based on natural feedstuffs customarily used in practical rations.

Requirements for vitamin A have been expressed in U.S.P. units of vitamin A activity per kg of feed. The international standards for vitamin A activity based on vitamin A and β-carotene are as follows: one International Unit (IU) of vitamin A = one U.S.P. unit = vitamin A activity of 0.300 μg of crystalline vitamin A alcohol corresponding to 0.344 μg of vitamin A acetate or 0.550 μg of vitamin A palmitate. β-Carotene is the standard for pro-vitamin A. One International Unit of vitamin A activity is equivalent to 0.6 μg of β-carotene; 1 mg of

TABLE 1. NUTRIENT REQUIREMENTS OF CHICKENS[1]

(In Percentage or Amount per Kg of Feed)

Nutrient	Starting Chickens 0–8 weeks	Growing Chickens 8–18 weeks	Laying Hens	Breeding Hens
Total protein, %	20	16	15	15
Vitamins				
Vitamin A activity (U.S.P. Units)[2]	2,000	2,000	4,000	4,000
Vitamin D (ICU)[3]	200	200	500	500
Vitamin E	see text			
Vitamin K_1, mg	0.53	?	?	?
Thiamine, mg	1.8	?	?	*0.8*
Riboflavin, mg	3.6	1.8	2.2	3.8
Pantothenic acid, mg	10	10	2.2	10
Niacin, mg	27	*11*	?	?
Pyridoxine, mg	3	?	3	*4.5*
Biotin, mg	0.09	?	?	*0.15*
Choline, mg[4]	1,300	?	?	?
Folacin, mg	*1.2*	?	0.25	0.35
Vitamin B_{12}, mg	0.009	?	?	*0.003*
Minerals				
Calcium, %	1.0	1.0	2.75[5]	2.75[5]
Phosphorus, %[6]	0.7	0.6	0.6	0.6
Sodium, %[7]	0.15	0.15	0.15	0.15
Potassium, %	0.2	0.16	?	?
Manganese, mg	55	?	?	33
Iodine, mg	0.35	0.35	0.30	0.30
Magnesium, mg	500	?	?	?
Iron, mg	40	?	?	?
Copper, mg	4	?	?	?
Zinc, mg	35	?	?	?

[1] These figures are estimates of requirements and include no margins of safety. (See text, page 2-5.) Italicized figures are tentative.

[2] May be vitamin A or pro-vitamin A.

[3] See text, page 3.

[4] See text, page 5.

[5] This amount of calcium need not be incorporated in the mixed feed, inasmuch as calcium supplements fed free-choice are considered as part of the ration.

[6] At least 0.5% of the total feed of starting chickens should be inorganic phosphorus. All the phosphorus of non-plant-feed ingredients is considered to be inorganic. Approximately 30% of the phosphorus of plant products is non-Phytin phosphorus and may be considered as part of the inorganic phosphorus required. A portion of the phosphorus requirement of growing chickens and laying and breeding hens must also be supplied in inorganic form. For birds in these categories the requirement for inorganic phosphorus is lower and not as well defined as for starting chickens.

[7] Equivalent to 0.37% of sodium chloride.

β-carotene = 1,667 IU of vitamin A. International standards for vitamin A are based on the utilization of vitamin A and β-carotene by the rat. In the chicken, as in the rat, 0.6 μg of β-carotene is equivalent to one U.S.P. unit of vitamin A, except when the carotene intake provides vitamin A activity greatly in excess of the requirement.

Requirements for vitamin D have been expressed in International Chick Units per kg of feed, inasmuch as chickens and birds generally use vitamin D_3 from fish oils and irradiated animal sterol effectively but do not use vitamin D_2 from irradiated ergosterol as efficiently as do rats and other mammals. One International Chick Unit (ICU) of vitamin D is equivalent to one IU or one U.S.P. unit, each of which is defined as the vitamin D activity of 0.025 μg of pure vitamin D_3. Vitamin D produced by irradiation of

TABLE 2. NUTRIENT REQUIREMENTS OF TURKEYS[1] (In Percentage or Amount per Kg of Feed)

Nutrient	Starting Poults 0–8 weeks	Growing Turkeys 8–16 weeks	Breeding Turkeys
Total protein, %[2]	28	20	15
Vitamins			
Vitamin A activity (U.S.P. Units)[3]	4,000	4,000	4,000
Vitamin D (ICU)[4]	900	900	*900*
Vitamin E	see text		
Vitamin K_1, mg	*0.7*	?	?
Thiamine, mg	*2*	?	?
Riboflavin, mg	3.6	?	*3.8*
Pantothenic acid, mg	11	?	*16*
Niacin, mg	*70*	?	?
Pyridoxine, mg	*3*	?	?
Choline, mg	1,900	?	?
Folacin, mg	0.9	?	*0.8*
Vitamin B_{12}, mg	*0.003*	?	?
Minerals			
Calcium, %	1.2	1.2	2.25[5]
Phosphorus, %[6]	0.8	0.8	0.75
Sodium, %[7]	0.15	0.15	0.15
Potassium, %	*0.4*	?	?
Manganese, mg	55	?	33
Iron, mg	*60*	?	?
Copper, mg	*6*	?	?
Zinc, mg	*70*	?	?

[1] These figures are estimates of requirements and include no margins of safety. (See text, page 2-5.) Italicized figures are tentative.

[2] The protein content of rations for growing turkeys from 16 weeks to market weight may be reduced to 16%.

[3] May be vitamin A or pro-vitamin A.

[4] See text, page 3.

[5] This amount of calcium need not be incorporated in the mixed feed, inasmuch as calcium supplements fed free-choice are considered as part of the ration.

[6] At least 0.5% of the total feed of starting poults should be inorganic phosphorus. All the phosphorus of non-plant-feed ingredients is considered to be inorganic. Approximately 30% of the phosphorus of plant products is non-Phytin phosphorus and may be considered as part of the inorganic phosphorus required. Presumably a portion of the requirement of growing and breeding turkeys must also be furnished in inorganic form.

[7] Equivalent to 0.37% of sodium chloride.

7-dehydro-cholesterol may be more efficiently utilized by growing chicks and turkey poults than vitamin D from fish oils. This difference in the efficacy of vitamin D from fish oils and irradiated animal sterols is particularly apparent when the ration is low in inorganic phosphorus. Turkeys are especially sensitive to the type of phosphorus in the diet in relation to the type of vitamin D used. These factors have been considered in arriving at the estimated requirements for vitamin D, and the requirements listed are based on suggested minimum quantities of inorganic phosphorus. With the suggested amount of inorganic phosphorus, no difference in efficacy of vitamin D from fish oils and irradiated animal sterols should be observed in practice.

Requirements for all other vitamins and for the trace elements have been expressed in mg per kg, while the requirements for protein, amino acids, calcium, phosphorus, potassium, and sodium have been given in percentages.

Betaine can be used interchangeably with choline to meet the needs of the chicken for methylating agents but will not replace choline for its other functions, such as perosis prevention. Betaine appears to be widely distributed in practical feedstuffs and

thus may be important in sparing choline. Likewise, vitamin B_{12} has been shown to reduce the requirement of the chick for choline. The figures for choline requirements given in the tables are intended to be applicable to conditions that would be encountered in practice.

The type of dietary carbohydrate has been shown to influence requirements of some of the water-soluble vitamins. Therefore, in establishing the requirements of these vitamins, greater weight was given to the results of experiments in which starch rather than one of the sugars was the principal dietary carbohydrate. This consideration was especially important in the case of folacin.

Requirements for vitamin E vary so much, depending on the nature of the diet, that it seemed inadvisable to include figures in the tables. Chicks have been reared on purified diets very low in fat without any detectable vitamin E. Vitamin E requirement is increased by high levels of unsaturated fats and decreased by the presence of antioxidants. A part, but not all, of the biological function of vitamin E can be fulfilled by selenium.

Need for a minimum level of inorganic phosphorus is indicated in the footnotes to Tables 1 and 2. This need is based on the generally greater availability of inorganic phosphorus than of Phytin phosphorus. Inorganic phosphorus supplements differ among themselves in availability, and it is important that the minimum level of inorganic phosphorus be provided in readily available form.

Experimental data that make it possible to give a more complete table of requirements for the essential amino acids have become available during the past several years. These requirements are given in Table 5.

This revision, like previous ones, gives tentative requirements for certain vitamins and minerals. In this revision, however, tentative values are listed in the same tables as the better-established values and are distinguished by italic type. In a sense, all the values are tentative inasmuch as they are subject to revision as new data become available. The values in italics are based on a limited number of observations or on conflicting reports.

It is impossible, of course, to give quantitative requirements for unknown dietary factors. Nevertheless, account must be taken of their existence. A diet that supplies the specified levels of the known nutrients but does not supply the unknowns is inadequate for best performance. There is evidence for four distinct growth factors in dried whey, marine and packinghouse by-products, distillers solubles, and certain green forages. Whether these materials differ from each other in the nature of their organic factors is not known. There is evidence for at least one unknown hatchability factor in fish solubles and green forage.

In recent years, several antibiotics have assumed an important place in poultry feeds because they increase growth rate and efficiency of feed utilization. They are not nutrients and it would not be appropriate to include them among the nutrient requirements. They appear to exert their effect upon the growth of the chicken by bringing about a change in the bacterial population of the digestive tract. Depending on the antibiotic used, 2 to 10 mg per kg of feed are needed to produce the desired effect.

TABLE 3. NUTRIENT REQUIREMENTS OF DUCKS[1]

(In Percentage or Amount per Kg of Feed)

Nutrient	Starting and Growing Ducks
Total protein, %	17
Vitamins	
Vitamin D (ICU)[2]	220
Riboflavin, mg	4
Pantothenic acid, mg	11
Niacin, mg	55
Pyridoxine, mg	2.6

[1] These figures are estimates of requirements and include no margins of safety.

[2] See text, page 2-5.

TABLE 4. NUTRIENT REQUIREMENTS OF PHEASANTS AND QUAIL[1]

(In Percentage or Amount per Kg of Feed)

Nutrient	Starting and Growing Pheasants	Starting and Growing Quail	Breeding Quail
Total protein, %	30[2]	28	?
Vitamins			
Vitamin A activity (U.S.P. Units)[3]	?	*13,000*	?
Vitamin D (ICU)[4]	*1,200*	?	?
Riboflavin, mg	*3.5*	?	?
Niacin, mg	*60*	?	?
Minerals			
Calcium, %	?	?	*2.3*
Phosphorus, %	*1.0*	?	*1.0*
Sodium, %[5]	*0.085*	*0.085*	?
Chlorine, %	*0.11*	*0.11*	?
Iodine, mg	*0.30*	*0.30*	?

[1] These figures are estimates of requirements and include no margins of safety. (See text, page 2-5.) Italicized figures are tentative.
[2] At energy level of 2,300 kcal of metabolizable energy per kg of feed.
[3] May be vitamin A or pro-vitamin A.
[4] See text, page 3.
[5] Equivalent to 0.21 % of sodium chloride.

TABLE 5. ESSENTIAL AMINO-ACID REQUIREMENTS OF CHICKENS AND TURKEYS[1]

Amino acid	Starting Chicks Percentage of Diet	Starting Poults Percentage of Diet	Laying Chickens Percentage of Diet
Arginine	1.2	1.6	0.8
Lysine	1.1	1.5	0.5
Histidine	0.4	?	?
Methionine	0.75	0.87	0.53
or			
{ Methionine	0.4	0.52	0.28
{ Cystine	0.35	0.35	0.25
Tryptophan	0.2	0.26	0.15
Glycine[2]	1.0	1.0	?
Phenylalanine	1.3	?	?
or			
{ Phenylalanine	0.7	?	?
{ Tyrosine	0.6	?	?
Leucine	1.4	?	1.2
Isoleucine	0.75	0.84	0.5
Threonine	0.7	?	0.4
Valine	0.85	?	?
Protein	20.0	28.0	15.0
Metabolizable energy, kcal/kg	2,750	2,450	2,850

[1] These figures are estimates of requirements and include no margins of safety.
[2] The chick can synthesize glycine but the synthesis does not proceed at a rate sufficient for maximum growth.

SYMPTOMS OF NUTRITIONAL DEFICIENCIES IN CHICKENS AND TURKEYS

Here we shall describe and illustrate the more common gross pathological symptoms seen in poultry maintained on diets deficient in the various nutritional factors. One shortcoming of such a description is that the symptoms are observed, for the most part, in poultry that are fed rations severely deficient in some specific factor. Under these conditions only the acute symptoms develop, which, in most cases, are quite characteristic for each nutritional factor, thus making a diagnosis relatively easy. On the other hand, the gross symptoms observed in chronic deficiency of any one of several factors may be similar (perhaps only retarded growth or ruffled plumage, for example), thus making an accurate diagnosis difficult if not impossible. The chronic deficiency may be more serious in the long run than the acute deficiency, since diagnosis and treatment of the acute deficiency may be readily obtained, while the chronic deficiency continues to exist because of failure to diagnose it.

VITAMIN A

On a severely deficient diet the symptoms of vitamin A deficiency in chicks begin to appear in approximately 3 weeks. Growth is markedly retarded and the chicks show general weakness, emaciation, staggering gait, and ruffled plumage (Figure 1). Resistance to infection is reduced and mortality is increased. The secretions of the intestinal mucous glands, the tear glands, and the salivary glands fail. An opaque appearance caused by keratinization of the third eyelid may be observed. Infection may occur, resulting in the production of a viscous fluid that may cause the eyelids to stick together.

Pathological lesions observed on autopsy are confined largely to the mucous membranes of the mouth, pharynx, esophagus, and respiratory and urinary systems. Creamy white pustules often are found on the roof of the mouth and along the esophagus, sometimes extending into the crop (Figure 2). Urates accumulate in the ureters and in the kidney tubules, causing these organs to become enlarged and creamy white in color (Figure 3). Because of its whitish appearance, this urate accumulation is detected easily on gross examination.

In mature fowl the symptoms noted for chicks may develop much more slowly, but the eye disorder often becomes more acute. A cheesy exudate from the eyes as well as a sticky discharge from the nostrils, is often observed. Egg production and hatchability are markedly reduced.

Symptoms of vitamin A deficiency in turkey poults are generally similar to those described for chicks, but are usually much more acute.

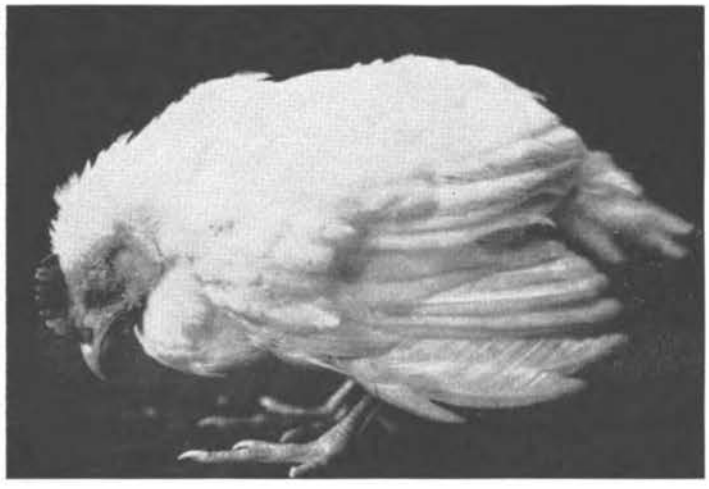

FIG. 1. An advanced stage of vitamin A deficiency. Note the exudate from the eye and the general ruffled appearance.

(Courtesy of the Department of Poultry Husbandry, Cornell University.)

FIG. 2. An advanced case of vitamin A deficiency showing the pharynx and esophagus studded with pustules.

(Courtesy of the University of California Agricultural Experiment Station.)

FIG. 3. Effect of vitamin A deficiency on the kidneys. Note the whitish urate deposits in the kidneys and the enlarged ureters.

(Courtesy of the University of Wisconsin Agricultural Experiment Station.)

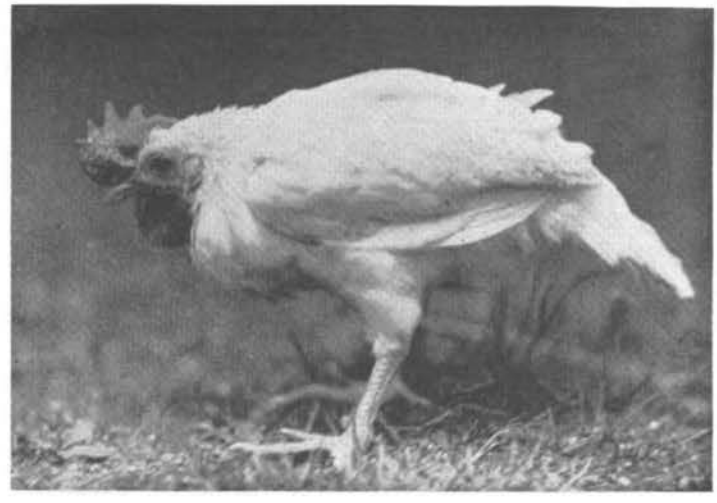

FIG. 4. A chick deficient in vitamin D, showing ungainly manner of balancing body. The beak is also soft and rubbery.

(Courtesy of the Department of Poultry Husbandry, Cornell University.)

VITAMIN D

A lack of vitamin D in the absence of direct sunlight results in the nutritional-deficiency disease termed rickets. The chicks are retarded in growth, show a disinclination to walk or walk with a lame stiff-legged gait, and have an ungainly manner of balancing the body (Figure 4). The chicks appear generally unthrifty. In this disorder an upset occurs in the mechanism involving the absorption and retention of calcium and phosphorus, as a result of which these minerals are not deposited in normal amounts in the bony structure of the body. Abnormal bone development may be detected most readily in the legs and at the junction of the ribs on the sides of the breast. The spinal column may be curved, and the sternum usually shows acute lateral bending or depression. Enlargement of the hock joints and beading of the rib ends become apparent. The beak is soft and rubbery and may be easily bent.

Inasmuch as vitamin D is involved in calcium and phosphorus absorption and retention, a deficiency of either of these mineral elements may cause symptoms some-

FIG. 5. α-Tocopherol deficiency in a young chick. Note loss of control of legs and head retraction.

(Courtesy of the Department of Poultry Husbandry, Cornell University.)

what similar to those described for vitamin D deficiency. The symptoms may not be grossly distinguishable one from another, except that the legs appear normal in phosphorus deficiency. Under practical conditions, however, vitamin D is the factor usually lacking, because a deficiency of calcium or phosphorus hardly ever becomes so acute as to bring about these symptoms.

In mature laying birds, the first symptom of a vitamin D deficiency is the laying of thin-shelled eggs, followed very shortly by decreased egg production. The breast bone becomes soft and rubbery, and the bones of the legs and wings become fragile and easily broken. Birds may temporarily lose the use of their legs and squat in a penguin-like manner, a symptom that sometimes has been called egg-paralysis. Hatchability is markedly reduced.

Symptoms of vitamin D deficiency in turkeys are very similar to those described for chickens, and are much more severe.

VITAMIN E

A lack of vitamin E in the ration of growing chicks results in the condition known as nutritional encephalomalacia. Chicks with this deficiency disease suddenly become prostrated, lying with legs outstretched and toes flexed (Figure 5). The head is retracted and often twisted laterally. Before the chicken becomes completely prostrated, its gait and other movements are often incoordinate. Upon autopsy, lesions are found in the cerebellum and sometimes in the cerebrum. In many chicks, necrotic reddish or brownish areas on the surface of the cerebellum can be seen by inspection. Under some conditions vitamin E deficiency results in subcutaneous edema and edema of the heart and pericardium.

In mature fowls, a prolonged vitamin E deficiency results in sterility in the male and reproductive failure in the female. Degenerative changes in the testes of the male may occur, resulting in permanent sterility. In females, egg production apparently is not affected by a vitamin E deficiency, while hatchability is reduced markedly. During incubation, embryonic growth and differentiation are slow, and many embryos die during the first two days of development because of circulatory failure. A definite critical period in the development of the embryo occurs about the fourth day.

Vitamin E deficiency in poults is known as nutritional myopathy. This condition is characterized by lesions in the muscular wall

of the gizzard. These lesions appear as circumscribed gray areas, which often are of firmer texture than normal muscle, and in some instances suggest the presence of scar tissue.

VITAMIN K

A lack of vitamin K greatly delays the clotting time of the blood, and chicks fed a deficient ration may bleed to death from any injury or bruise that causes rupture of blood vessels. Hemorrhages may occur subcutaneously, intramuscularly, intraperitoneally, or in any part of the chick's body (Figure 6). The hemorrhages vary in size and appear to be the only symptoms of the deficiency.

Mature birds do not seem to be subject to acute vitamin K deficiency, indicating that they may synthesize the vitamin to some extent. It has been shown, however, that laying birds fed a diet low in vitamin K produce eggs low in vitamin K. When these eggs are incubated, chicks with very low reserves of vitamin K are hatched, with an accompanying prolonged blood-clotting time. As a consequence, the chicks may bleed to death from an injury similar to that produced by wing-banding.

THIAMINE

Day-old chicks placed on a ration low in thiamine develop polyneuritis within 9 to 12 days. In the acute stage of polyneuritis the head may be drawn over the back (Figure 7). Diets containing suboptimal amounts of thiamine lead to loss of appetite, emaciation, impairment of digestion, general weakness, and frequently to convulsions.

Symptoms of thiamine deficiency in mature birds and turkeys are similar to those described for chicks.

RIBOFLAVIN

A lack of riboflavin in the diet of young chicks results in diarrhea, retarded growth, and paralysis of the legs, sometimes called curled-toe paralysis. It involves the legs and feet and occurs in two stages—a preliminary stage that is curable and an acute stage that is incurable. Nutritional paralysis is characterized by the sudden appearance of chicks walking on their hocks, with toes curling inward; otherwise, the chicks appear to be in excellent health (Figure 8). Chicks receiving rations only partly deficient in riboflavin often recover spontaneously. In severe cases of nutritional paralysis the brachial and

FIG. 6. Generalized hemorrhage in a young chick caused by a vitamin K deficiency.

(Courtesy of the Department of Poultry Husbandry, Cornell University.)

FIG. 7. Head retraction caused by a deficiency of thiamine.

(Courtesy of the University of Wisconsin Agricultural Experiment Station.)

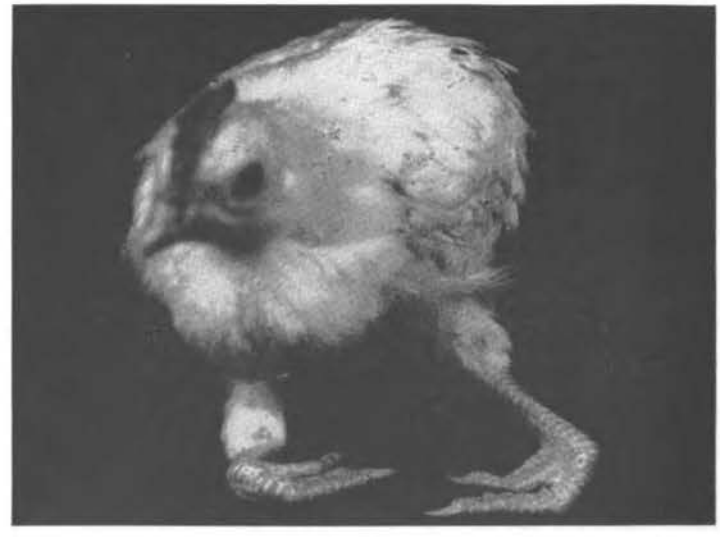

FIG. 8. Riboflavin deficiency in a young chick. Note the curled toes and tendency to squat on hocks.

(Courtesy of the Department of Poultry Husbandry, Cornell University.)

sciatic nerves show very marked hypertrophy and softening, which are usually discernible by inspection. The nerves occasionally reach a diameter of four or five times greater than normal.

Riboflavin deficiency in breeding birds results in poor hatchability. The requirement for hatchability is considerably higher than that for egg production and maintenance of health. The embryos that fail to hatch because of riboflavin deficiency are dwarfed and show a high incidence of edema, degeneration of the Wolffian bodies, and a characteristically defective down development, termed "clubbed down." On a ration moderately deficient in riboflavin, many embryos die during the second week of incubation. The mortality reaches a peak about the eleventh day of development.

PANTOTHENIC ACID

Pantothenic acid deficiency in young chicks results in retarded growth, and feather de-

velopment is extremely ragged. Within 12 to 14 days a viscous exudate causes the eyelids to become granular and stick together. Crusty scabs appear at the corners of the mouth and around the vent (Figure 9). Dermatitis of the feet sometimes is observed in pantothenic acid deficiency, though the lesions are seldom as severe as those brought about by a biotin deficiency. Liver damage and changes in the spinal cord may be seen on postmortem examination.

Lesions in adult fowl similar to those in growing chicks have not been observed, although a deficiency of pantothenic acid results in lowered hatchability.

NIACIN

A deficiency of niacin in the diet of chicks results in black tongue, a condition 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 with a deep red color in contrast to the normal pink of healthy chicks. Growth is retarded (Figure 10) and feed consumption is reduced. Poor feather development and occasionally scaly dermatitis of the feet and skin are also observed.

Turkey poults fed a diet deficient in niacin

FIG. 9. An advanced stage of pantothenic acid deficiency. Note the lesions at the corners of the mouth and on the eyelids and feet.

(Courtesy of the Department of Poultry Husbandry, Cornell University.)

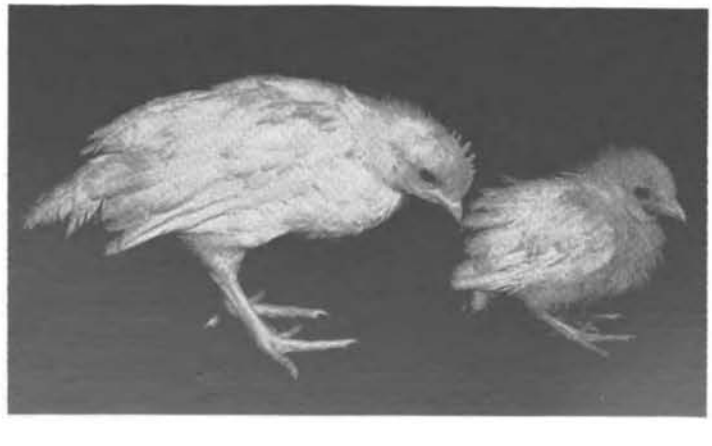

FIG. 10. Effect of niacin deficiency on chick growth.

(Courtesy of the University of Wisconsin Agricultural Experiment Station.)

develop a hock disorder similar to perosis. The same condition can be produced somewhat less readily in chicks.

VITAMIN B_6

Chicks fed a diet deficient in vitamin B_6 show a small initial gain, then cease to grow or begin to grow very slowly. Some chicks show abnormal excitability and convulsive movements. Chicks may suddenly run about aimlessly, often flopping their wings and keeping their heads down. Convulsions may occur and during these convulsions the chick may rest on its breast, raise its feet off the floor, and flop its wings. Chicks may fall on their sides or roll over on their backs and rapidly paddle their feet. The head often jerks up and down or retracts, as in polyneuritis, and sometimes moves convulsively in an up-and-down movement with the neck extended or twisted. Complete exhaustion follows such convulsions and is frequently fatal.

Vitamin B_6 deficiency in mature birds is characterized by loss of appetite, followed by rapid loss of weight and death. Egg production and hatchability are markedly reduced.

CHOLINE

Retarded growth and perosis suggest lack of choline in the diet of young chickens and turkeys (see Manganese). Choline deficiency in mature birds has been reported to result in increased mortality and lowered egg production, with an increased abortion of egg yolks from the ovaries. More recently, however, experiments reported from two laboratories have indicated that choline may be synthesized by the laying hen in quantities adequate for egg production.

BIOTIN

Biotin deficiency in chicks results in a dermatitis somewhat similar to that observed in pantothenic acid deficiency. Lesions first appear in about 3 weeks, although considerable variation in time of appearance has been noted. The bottoms of the feet become rough and calloused and hemorrhagic cracks appear (Figure 11). The toes may become necrotic and slough off, but the top of the foot and the leg usually show only a dry scaliness. Mandibular lesions that first appear in the corners of the mouth spread to include the area around the beak. Eyelids eventually become swollen and stick together. In contradistinction to these symptoms, the lesions in pantothenic acid deficiency are first evident in the corners of the mouth and eyes, and only in extreme cases do the lesions of the feet become so severe.

Biotin has been reported necessary for the prevention of perosis in chicks and turkeys. Turkey poults exhibit symptoms very similar to those described for chicks when fed a biotin-deficient ration.

Feeding mature fowl a biotin-deficient ration causes reduced hatchability, but egg production is not adversely affected. This indicates that the requirement of biotin for producing hatching eggs is higher than that for maintaining good health and egg production. In hens, dermatitis similar to that of chicks fed biotin-deficient rations has not been observed.

FOLACIN

Folacin deficiency in young chicks results in retarded growth, poor feathering, and, in colored chicks, feather depigmentation. These symptoms are accompanied by the development of an anemia that is characterized by a reduction in number of red blood cells and in hemoglobin. The red-cell size and the hemoglobin content of the cells, however, are increased. The red blood cells are also abnormally shaped and less fragile than normal. In poults, broken flight feathers, hock disorder, and cervical paralysis are common symptoms of folacin deficiency.

FIG. 11. Biotin deficiency. Note the severe lesions on the bottom of the feet.

(Courtesy of the University of Wisconsin Agricultural Experiment Station.)

FIG. 12. Perosis or slipped tendon resulting from a deficiency of manganese. A deficiency of either choline or biotin may also result in perosis.

(Courtesy of the Department of Poultry Husbandry, Cornell University.)

VITAMIN B_{12}

Vitamin B_{12} has been shown to be essential for chick growth and hatchability. There is a marked carry-over of the vitamin from the breeding hen to the young chick and mortality may be high among chicks deficient in the factor at hatching time.

CALCIUM AND PHOSPHORUS

Calcium, phosphorus, and vitamin D are closely interrelated in bone formation. A deficiency of any one of these results in rickets, although the blood picture may vary, depending on the factor that is lacking. Retarded growth and increased mortality are also symptoms of calcium and phosphorus deficiency.

MANGANESE

A manganese deficiency in the diet of growing chicks and poults results in perosis or slipped tendon (Figure 12). As has been mentioned, perosis may also be caused by a deficiency of choline or biotin.

Perosis is a malformation of the bones. The

symptoms 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 excessive quantities of calcium and phosphorus in the ration.

In laying and breeding birds, a manganese deficiency results in lowered egg production, eggshell strength, and hatchability. Numerous embryos that die as a result of manganese deficiency exhibit chondrodystrophy, a condition characterized by a parrot-like beak, wiry down, and shortening of the long bones. This condition is not, however, specific for manganese deficiency.

MAGNESIUM

When fed a diet deficient in magnesium, chicks grow slowly for about 1 week, then cease growing and become lethargic. When disturbed, they exhibit symptoms similar to those of other species fed diets deficient in magnesium. Chicks show a brief convulsion, then go into a comatose state that sometimes terminates fatally but usually ceases in a few minutes.

IODINE

Iodine deficiency in the chick's diet results in goiter. The thyroid gland increases to many times the normal size. Histological examinations of the enlarged thyroid glands show an absence of colloid and a hyperplasia.

IRON AND COPPER

Anemia is the result of an iron and copper deficiency in the chick's diet. This type of anemia is characterized by a reduction in the hemoglobin content of the blood and a reduction in the size of the red blood cell. A reduction in number of red cells, however, does not usually occur.

ZINC

In zinc deficiency, growth is retarded and feather development is extremely poor. The long bones of the legs and wings become shortened and thickened and the hocks become enlarged. Slipped tendon, however, does not develop as in manganese deficiency, but bone ash is at times slightly reduced. Occasionally the skin on the foot pads becomes dry and thickened, and fissures in the epidermis, which penetrate into the subcutaneous tissue, develop. The principal lesion is that of hyperkeratosis.

COMPOSITION OF FEED INGREDIENTS AND FEED REQUIRED FOR PRODUCTION

Early editions of this report contained tables on the composition of ingredients commonly used in poultry feeding. As in the 1960 edition, such tables have been omitted from this edition in the interest of economy. For information on feed composition the reader is referred to Publication 1232 of the National Academy of Sciences—National Research Council entitled *Joint United States-Canadian Tables of Feed Composition.*

Data showing the approximate quantities of feed required for the production of eggs are presented in Table 6. Data on the quantities of feed required and the time required to attain certain weights in chicks and turkeys are given in Tables 7 and 8. The figures given are typical values for the breed represented. Considerable variation from the figures given may result because of strain variation, the amount of feed wasted, and quality of feed. They are presented to serve as a guide in estimating the amount of feed required for a given purpose.

TABLE 6. FEED REQUIRED BY CHICKENS OF DIFFERENT LIVE WEIGHTS FOR MAINTENANCE AND FOR PRODUCTION OF 0, 100, 200, AND 300 EGGS, RESPECTIVELY, PER YEAR

Average Live Weight		Average Total Feed Required per Bird per Year for Maintenance and the Production of the Indicated Number of Eggs			
		0 Eggs per Year	100 Eggs per Year	200 Eggs per Year	300 Eggs per Year
kg	lb	kg	kg	kg	kg
1.36	3.0	21.5	28.0	34.0	40.5
1.59	3.5	23.5	30.5	36.5	43.0
1.81	4.0	25.5	32.5	38.5	45.0
2.04	4.5	27.5	34.0	40.5	47.0
2.27	5.0	29.5	36.0	42.5	49.0
2.50	5.5	31.5	38.0	44.5	51.0
2.73	6.0	33.5	40.0	46.5	52.5
2.95	6.5	35.5	42.0	48.0	54.5
3.18	7.0	37.0	43.5	50.0	56.5

TABLE 7. FEED REQUIRED AND TIME REQUIRED TO OBTAIN CERTAIN AVERAGE LIVE WEIGHTS WITH COMMON BREEDS OF CHICKENS

Average Live Weight	Kind of Chicken and Quantity of Feed Required per Bird				Kind of Chicken and Age at Which Certain Live Weights Are Reached			
	White Leghorns		Heavy Breeds		White Leghorns		Heavy Breeds	
	Females	Males	Females	Males	Females	Males	Females	Males
kg	kg	kg	kg	kg	wk	wk	wk	wk
0.25	0.5	0.45	0.45	0.4	3.2	2.9	3.0	2.7
0.5	1.15	1.0	0.95	0.9	5.8	5.0	4.7	4.3
0.75	1.85	1.6	1.55	1.45	8.2	6.8	6.1	5.5
1.0	2.65	2.35	2.25	2.1	10.6	8.3	7.5	6.7
1.25	3.8	3.15	3.05	2.75	13.3	9.7	8.9	7.8
1.5	5.3	4.1	3.9	3.45	16.4	11.3	10.3	8.7
1.75	8.2	5.3	5.0	4.25	19.8	13.0	11.6	9.7
2.0			6.2	5.1			13.0	10.6

TABLE 8. FEED REQUIRED AND TIME REQUIRED TO OBTAIN CERTIAN AVERAGE LIVE WEIGHTS WITH TWO COMMON BREEDS OF TURKEYS

Average Live Weight	Kind of Turkey and Quantity of Feed Required per per Bird				Kind of Turkey and Age at Which Certain Live Weights are Reached			
	Beltsville Small White		Broad-Breasted Bronze		Beltsville Small White		Broad-Breasted Bronze	
	Females	Males	Females	Males	Females	Males	Females	Males
kg	kg	kg	kg	kg	wk	wk	wk	wk
0.25	0.3	0.3	0.3	0.3	2.7	2.4	2.0	1.8
0.5	1.0	0.95	0.75	0.75	4.7	4.2	3.5	3.3
1.0	2.45	2.25	1.75	1.6	7.4	6.6	5.6	5.2
1.5	3.95	3.55	3.0	2.6	9.6	8.4	7.0	6.9
2.0	5.45	4.8	4.25	3.9	11.6	9.8	8.3	7.6
2.5	7.05	6.2	5.6	5.1	13.7	11.2	9.7	8.7
3.0	9.2	7.55	7.2	6.35	16.4	12.5	11.0	9.6
4.0		10.8	10.6	9.1	22.5	14.7	13.5	11.2
5.0		14.75	15.0	12.35		17.9	16.3	13.1
6.0		20.55	20.45	15.8		21.5	19.2	14.9
7.0			26.65	19.25			23.1	16.8
8.0				23.15				18.6
9.0				27.2				20.5
10.0				31.75				22.3

DAILY REQUIREMENTS

The daily nutrient requirements for light and heavy breeds of chickens, presented in Tables 9 and 10, were computed from values given in Tables 1 and 7. It is hoped that these figures will be of value in studies on comparative nutrition. By expressing the requirements for all species and types of farm animals on a uniform basis, any basic relationships in their nutritive requirements will be made apparent.

TABLE 9. DAILY NUTRIENT REQUIREMENTS PER ANIMAL

(S.C. White Leghorns or Similar Breeds)

	GROWING ANIMAL						MATURE ANIMAL		
							Maintenance	Laying 60% Production	Breeding
Body weight, g	250	500	750	1,000	1,250	1,500	1,800	1,800	1,800
Total daily feed, g	27	45	57	65	79	84	70	110	110
Crude protein, g	5.4	9	10.1	10.4	12.6	13.4	?	16.5	16.5
Calcium, g	0.27	0.45	0.57	0.65	0.79	0.84	?	3	3
Phosphorus, g	0.19	0.31	0.40	0.39	0.47	0.50	?	0.66	0.66
Sodium, g	0.040	0.067	0.085	0.097	0.119	0.126	?	0.165	0.165
Potassium, g	0.054	0.090	0.114	0.103	0.127	0.134	?	?	?
Magnesium, mg	13	22	28	?	?	?	?	?	?
Manganese, mg	1.4	2.4	3.1	?	?	?	?	?	3.6
Iodine, mg	0.009	0.015	0.020	0.023	0.028	0.029	?	0.033	0.033
Vitamin A, U.S.P. Units	54	90	114	130	158	168	?	440	440
Vitamin D, ICU	5.4	9	11.4	13	15.8	16.8	?	55	55
Thiamine, mg	0.048	0.081	0.103	?	?	?	?	?	0.088
Riboflavin, mg	0.096	0.162	0.206	0.117	0.142	0.151	?	0.242	0.420
Pantothenic acid, mg	0.27	0.45	0.57	0.65	0.79	0.84	?	0.242	1.10
Niacin, mg	0.73	1.21	1.54	0.71	0.87	0.92	?	?	?
Pyridoxine, mg	0.081	0.13	0.17	?	?	?	?	0.33	0.49
Biotin, mg	0.0024	0.0040	0.0051	?	?	?	?	?	0.016
Choline, mg	35	58	74	?	?	?	?	?	?
Folacin, mg	0.032	0.054	0.068	?	?	?	?	0.027	0.038
Vitamin B_{12}, mg	0.00024	0.00040	0.00051	?	?	?	?	?	0.00033

TABLE 10. DAILY NUTRIENT REQUIREMENTS PER ANIMAL

(Chickens of the Heavy Breeds)

	GROWING ANIMAL					MATURE ANIMAL		
						Maintenance	Laying 60% Production	Breeding
Body weight, g	250	500	750	1,000	1,500	2,500	2,500	2,500
Total daily feed, g	35	57	73	84	100	87	125	125
Crude protein, g	7	11	15	17	20	?	18.7	18.7
Calcium, g	0.35	0.57	0.73	0.84	1	?	3.44	3.44
Phosphorus, g	0.24	0.40	0.51	0.59	0.70	?	0.75	0.75
Sodium, g	0.052	0.085	0.10	0.12	0.15	?	0.19	0.19
Potassium, g	0.070	0.114	0.14	0.17	0.20	?	?	?
Magnesium, mg	17	28	36	42	50	?	?	?
Manganese, mg	1.9	3.1	4	4.6	5.5	?	?	4.1
Iodine, mg	0.011	0.020	0.025	0.029	0.035	?	0.037	0.037
Vitamin A, U.S.P. Units	70	114	146	168	200	?	500	500
Vitamin D, ICU	7	11.4	14.6	16.8	20	?	62	62
Thiamine, mg	0.063	0.10	0.13	0.15	0.18	?	?	0.10
Riboflavin, mg	0.12	0.20	0.26	0.30	0.36	?	0.27	0.48
Pantothenic acid, mg	0.35	0.57	0.73	0.84	1	?	0.27	1.25
Niacin, mg	0.95	1.53	1.97	2.3	2.7	?	?	?
Pyridoxine, mg	0.10	0.17	0.22	0.25	0.30	?	0.37	0.56
Biotin, mg	0.0031	0.0051	0.0066	0.0076	0.0090	?	?	0.018
Choline, mg	45	74	95	109	130	?	?	?
Folacin, mg	0.042	0.068	0.088	0.100	0.120	?	0.031	0.043
Vitamin B_{12}, mg	0.00032	0.00051	0.00066	0.00076	0.00090	?	?	0.00037

SUMMARY

This condensed report brings together available reliable information regarding the nutritional requirements and the symptoms of nutritional deficiencies of poultry. It should be useful to all who are concerned with the formulation and manufacture of poultry rations and with the teaching of poultry nutrition. County agricultural agents, high school teachers, and feedmen who do not have library facilities or the time to study the original reports in the literature will also find it useful in answering questions regarding problems of poultry nutrition.

The dietary requirements should serve as a yardstick in determining the adequacy of any particular ration, at least for the better-known nutritional factors. It should be emphasized, however, that the dietary requirements listed do not represent all the nutritional factors required by poultry for optimum results. Much evidence suggests that other nutritional factors remain to be isolated and identified.

A brief description of the more common gross pathological symptoms that are observed in poultry receiving nutritionally inadequate diets has been included to aid in recognizing the diseases resulting from nutritional deficiency. Very probably some of these will never appear under practical conditions. On the other hand, deficiencies of vitamin A, vitamin D, riboflavin, and manganese may occasionally appear among growing chicks and breeding hens. It is hoped that the description of the symptoms along with the photographs of actual cases will aid in early recognition and treatment of diseases resulting from nutritional deficiency.

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