POULTRY NUTRITION AND FEEDING

- *References: Jurgens (2002) & NRC (1994) as the main sources with Hooge (1998) in Kellems and Church (1998), Waldroup, P. W. [2001. Dietary nutrient allowances for chickens and turkeys. Feedstuffs 73(29):56-65], and Larbier and Leclercq [1992. Translation by J. Wiseman (1994)].*

INTRODUCTION

1. **Poultry Nutrition in General**

   A. Poultry - Any of the domesticated and commercialized types of birds used for production of eggs and(or) meat for human food (. . . also for other purposes though!).

      ◦ e.g., Chickens, turkeys, pigeons, peafowl, ducks, geese, upland game birds (quail, pheasant, partridges . . .) and ratites (ostriches, emu . . .).

   B. Chickens, turkeys and laying hens have been commercially produced in the confinement system for more than 70 years:

      1) For each species, the NRC includes suggested requirements for 14 amino acids, 12 minerals, 13 vitamins, and one fatty acid.
      2) Should be aware that those recommendations are based on limited and, sometimes, very old information (especially true with some vitamins & trace minerals).
      3) Thus, many gaps in the information pool for optimum production exist.

2. **Commercial Poultry Production/Industry**

   A. Has been an innovator and applicator of advancing technology and knowledge to keep meat and egg prices relatively constant for decades.
   B. Feed? Feed cost is the largest single item in poultry production & accounts for 60 to 75% of the total production cost . . . from hatching eggs to processing plant.

      1) Much emphasis has been placed on least-cost feed formulation and getting the lowest feed cost per unit of salable product.
      2) To do so, necessary to refine energy and nutrient requirements, disease control, genetic improvement, and housing & equipment.
      3) All those efforts led to steady improvements in growth rate, feed conversion, and livability under intensive commercial conditions.

POULTRY DIETS IN GENERAL

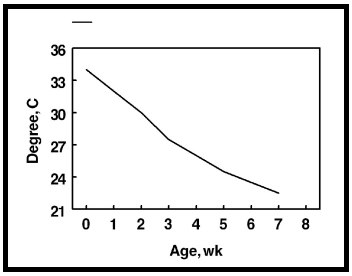
1. **Diet Formulation** - Steps involved poultry diet formulation are similar to formulating diets for pigs.

2. Feed Ingredients and Additives

A. Corn and soybean meal - Usually the most plentiful and lowest-cost sources of energy and well-balanced protein, thus extensively used, especially in the US.
B. Fish meals and meat meals - Good sources of protein and amino acids, and also contain bone, which is a source of highly available Ca and P. Add 2 to 5% of the diet depending on their prices.
C. Ca & P - Major minerals. Only 30 to 40% of plant P is non-phytin P, which is available to poultry. Should either increase the availability somehow or supplement with inorganic sources.
D. Salt - 0.2 to 0.5% is added to most poultry diets.
E. Supplemental lipids (up to 5% of the diet) - May increase energy utilization through a reduced passage rate an others? Also, can reduce the heat increment.
F. Yellow pigmentation - Use as much yellow corn as possible plus good sources of xanthophyll, such as alfalfa meal or corn gluten meal, for the yellow coloration of the shanks, feet, skin, and egg yolks?
G. Non-nutritive additives are used for a variety of reasons - e.g., antibiotics (to stimulate growth & control diseases), arsenicals and nitrofurans (to improve performance), antiparasitic compounds, antioxidative, and antifungal compounds.

ENERGY AND NUTRIENTS FOR POULTRY

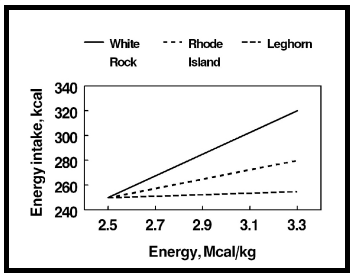
1. Energy, Protein and Amino Acids

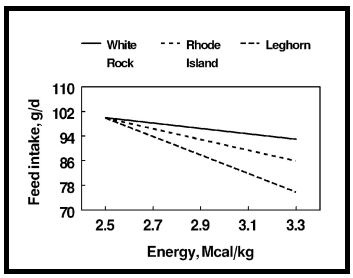


A. Energy requirement:

1) Comfort zone - ≈ 68 to 82°F (20 to 27.8°C):

a) Can expect "optimum" metabolic activity, i.e., no panting, cold stress, etc.
b) But, very young birds need a warmer temperature until they can maintain their body temperature at about 10 d of age. [Fgure - "Thermo-neutral temperature of the young bird (Larbier & Leclercq, 1992)"]





☞ Thus, younger birds can tolerate heat-stress better - Broilers over 4 wk & turkeys over 10 wk of age are most susceptible to heat stress!

2) Impossible to set the energy requirement in terms of unit/kg diet because birds adjust their feed intake to achieve the daily energy intake? [Figure - Effect of the energy density on feed intake (Larbier & Leclercq, 1992)]

B. Protein requirement?

1) Dietary energy content must be specified to maintain the proper ratio of protein to energy so that birds can consume an adequate amount of protein.
2) The protein requirement or amino acid requirements can be defined accurately only in relation to the energy density. Also, the degree of fat deposition in meat producing birds can be affected by the relationship.
3) Ideal protein concept? - See Section 7 on "Protein."
4) Some variability in the optimal protein:energy concept?

a) Some combinations of fats and carbohydrates have a protein-sparing effect.
b) Perhaps, deliberately altered in some instances to influence fat deposition.

C. Methionine would be the first-limiting amino acid in grain & soybean meal diets, but Lys is likely to become the first-limiting amino acid if soybean meal is replaced by another plant protein supplement such as cottonseed meal.
D. Restricting protein/amino acids (& energy) to retard growth (e.g., pullets of modern broiler strains grow at a rapid rate and also mature sexually at an early age)?

1) Necessary to retard growth and delay the onset of sexual maturity to optimize the egg production and the production of viable chicks.
2) Feeding programs to retard growth?

a) From the beginning of the 7^{th} or 9^{th} wk, limit the total feed allowed per bird per day (to 70%?) - Continue until placing on the standard laying diet at the beginning of the 23^{rd} wk.
b) Feed the birds on the "skip-a-day program" from the 7^{th} or 9^{th} wk to the 23^{rd} wk - Allows the pullets all the feed they will consume on one day and only 2 lb of grain per 100 birds on the alternate day.
c) Use a diet containing only 10 to 10.5% protein - Feed from the beginning of the 7^{th} or 9^{th} wk until placing on the laying diet.
d) Use a diet that contains 0.40 to 0.45% Lys and 0.60 to 0.70% Arg after the 7^{th} or 9^{th} wk (12.5 to 13% CP) - Imbalance of amino acids would depresses "appetite!"

2. **Vitamins**

A. Vitamin & trace mineral supplementation? Contributions to the overall feed cost are not much ($2.50 to 7.50/ton), but vitamins & minerals play major roles in the metabolic functions of poultry.

B. Because of the variations in the content, availability, and stability, premixes are formulated to assure adequacy, rather than just satisfying the NRC recommendations - See "Recommended supplemental vitamins for various classes of poultry (per ton of complete feed (Waldrop, 2001)."
C. Vitamin D - Expressed in ICU, which are based on the activity of D_3 because birds do not use D_2. (Turkeys are especially sensitive!)
D. Vitamin E - Requirements vary greatly depending on dietary lipids, Se, and antioxidant.
E. Some vitamins that were thought to be adequate in feeds and feed ingredients in the past, but may be questioned? - Perhaps, associated with the processing method (e.g., the use of expanders in mills for steam-conditioning feed to reduce/eliminate *Salmonella*)?

1) Folacin and biotin - Now added to some turkey diets to prevent the deficiency.
2) Niacin - May be required for laying and breeding hens. But, the requirement is so low that it will always be exceeded by natural feed ingredients?

F. Choline:

1) Growing chickens can use betaine interchangeably with choline for the methylation function, but it cannot replace choline to prevent perosis. Still, can spare choline!
2) Also, vitamin B_{12} can reduce the choline requirement.

Vitamin	*Unit*	*Starting (0-8 wk)*	*Growing (8-18 wk)*	*Hens (egg-type)*	*Breeders*	*Turkey (0-8 wk)*	*Turkey (8 wk-Mkt)*	*Turkey (breeder)*
A	MIU	7.0	7.0	6.0	8.0	9.0	7.0	9.0
D3	MIU	2.0	2.0	2.0	2.0	3.0	2.5	3.0
E	TIU	6.0	6.0	5.0	10.0	11.0	8.0	30.0
B12	mg	10.0	10.0	6.0	10.0	6.0	6.0	8.0
Roboflavin	g	6.0	6.0	4.0	5.0	6.0	4.0	5.0
Niacin	g	30.0	30.0	15.0	20.0	65.0	45.0	30.0
Pantothenic acid	g	10.0	10.0	6.0	9.0	14.0	10.0	17.0
Choline	g	450.0	450.0	250.0	350.0	600.0	550.0	400.0
K3	g	1.0	1.0	0.3	0.6	0.6	0.6	0.6
Folic acid	g	0.6	0.6	0.2	0.5	1.0	0.7	1.2
Thiamin	g	1.0	1.0	1.0	1.0	1.0	1.0	2.0
Pyridoxine	g	3.0	3.0	1.0	2.0	3.0	2.0	3.0
Biotin	mg	50.0	30.0	30.0	100.0	100.0	50.0	100.0

MIU = milllion international unit
TIU = thousand international unit

Mineral	*Unit*	*Starting (0-8 wk)*	*Growing (8-18 wk)*	*Hens (egg-type)*	*Breeders*	*Turkey (0-8 wk)*	*Turkey (8 wk-Mkt)*	*Turkey (breeder)*
Mn	mg	25.0	25.0	50.0	75.0	50.0	50.0	50.0
Zn	mg	25.0	25.0	50.0	75.0	50.0	50.0	50.0
Fe	mg	50.0	50.0	50.0	50.0	50.0	50.0	50.0
Cu	mg	5.0	5.0	5.0	5.0	5.0	5.0	5.0
I	mg	0.2	0.2	0.2	0.2	0.2	0.2	0.2
Se	mg	0.05	0.05	0.05	0.05	0.1	0.1	0.1

3. **Minerals**

A. See some comments for vitamins in general and the table containing the recommended supplemental trace minerals (per pound of mixed feed; Waldroup, 2001).
B. Ca - Perhaps, more difficult one to define the requirement, and the problem cannot be solved by simply adding a generous amount simply because excess Ca interferes with utilization of P, Mg, Mn, and Zn and it can reduce palatability of the diet.
C. Inorganic P - A greater availability vs. phytin P, but some variations in the availability.
D. The use of phytase in poultry diets has been increasing in recent years.
E. Trace minerals - Ones complexed with amino acids or protein have increased in commercial use in recent years because of higher availability, e.g., Zn-Met & Se-Met.

4. **Unidentified Nutrients?**

   A. With the identification of vitamins & considering some findings on the essentiality or significance of some trace mineral elements, many are disregarding the importance of so called, "unidentified growth factors."
   B. Still some responses? - Attributable to "truly" unidentified nutrient(s), or more likely to changes in feed palatability and(or) quality, mineral chelation, or simple improvement in the balance of available nutrients (NRC, 1994)?

5. **Some Additives** (Briefly mentioned some in the Introduction)

   A. Antibiotics - Since 1950 or so, several antibiotics have become important additives in broiler and market turkey feeds to improve growth rate and feed efficiency. Also, egg production may be improved with dietary supplementation.
   B. Antioxidants - Compounds used to prevent oxidative rancidity in fat, e.g., BHT, BHA & ethoxyquin.
   C. Grits - Hard insoluble or soluble particles, which remain trapped in the thick-muscled gizzard to facilitate grinding of feed. e.g., oyster or clam shells, limestone, gravel, pebbles or granite products. When mash or finely ground feeds are used, the value of grits is diminished.
   D Xanthophylls - Produce a deep yellow color in the beak, skin, shanks, feet, fat, and egg yolks of poultry. Many consumers believe that a deep yellow color of broiler skin/shanks and egg yolks is indicative of top quality. (See the table)

Xanthophyll and Lutein content (mg/kg): (NRC, 1994)

Ingredients	Xanthophyll	Lutein
Alfalfa meal, 17% CP	220	143
Alfalfa meal, 22% CP	330	-
Alfalfa protein concetrate, 40% CP	800	-
Algae meal	2,000	-
Corn	17	0.12
Corn gluten meal, 60% CP	290	120
Marigold petal meal	7,000	-

VARIOUS POULTRY DIETS

1. **Starter Diets** [e.g., See the table (Hooge, 1998)]

   A. Usually fed first 2 to 3 wk to chickens and 2 to 4 wk to turkeys.
   B. Higher energy and nutrient contents vs. others, especially protein/amino acids, but Leghorn-type pullets are fed diets with lower protein until 6 wk or so.
   C. Include high doses of antibiotics to reduce mortality and initiate more rapid growth and also a suitable coccidiostat.

2. **Broiler Diets**

   A. Fed as a complete feed to meat-type birds - May be fed in crumbles or pelleted form.
   B. A higher vitamin supplementation to meet the added requirements for growth under the stressful conditions encountered in the average broiler operation.
   C. May contain 3 to 5% added fat to increase the energy content and the protein content is adjusted to maintain an optimum protein:calorie ratio.

D. Fortified with antibiotics and should contain a coccidiostat.
E. Generally, two types: grower diets, fed from 3 wk to 6 wk of age, and finisher or withdrawal diets, fed from 6 wk to market age.

3. **Turkey Growing and Finishing Diets**

A. Similar to broiler diets and fed as a complete feed to meat-type birds.
B. Generally, use diets with a different CP content for 4- 8, 8-12, 12-16, 16-20 wk, and over 20 wk of age.

4. **Growing Diets and Developers for Leghorn-Type Chickens**

A. Designed to be fed to the replacement stock from 6 wk to sexual maturity.
B. Two types: 1) Complete feed, mash or pelleted - Generally lower in protein than starter diets, and 2) Mash concentrate - Fed with varying amounts of grain to meet the needs.

5. **Laying Diets for Leghorn-Type Chickens**

A. Diets fed to mature hens during egg production (e.g., see the table).
B. Two ways/types: 1) complete feed - mash or pelleted, and 2) mash concentrate to be fed with a specified amount of grain or mixed with grain & soybean meal.
C. The salt content may be decreased to reduce the incidence of wet droppings.
D. Cage fatigue? - Perhaps, the result of a Ca deficiency? If so, the Ca content should be increased, or provide a Ca source on a free choice basis.
E. Hens producing hatching eggs? - Should be fed a more highly fortified feed (especially, vitamins) than hens kept merely for commercial egg production.
F. Increase protein and vitamins during the period of stress or slumps in egg production. Also, use a higher dose of an antibiotic or a combination of antibiotics?

Examples of broiler starter, turkey starter, and caged layer peak egg production feeds[a] [Hooge (1998) in Kellems & Church (1998)]

Item	Broiler Starter (%)	Turkey Starter (%)	Layer Peak (%)
Ingredient			
Corn, yellow	56.45	47.75	60.50
Soybean meal (47.5% CP)	27.33	38.83	21.50
Meat and bone meal (50% CP)	7.00	-	5.09
Meat meal (56% CP)	-	9.50	-
Bakery by-product	6.00	-	-
Animal-vegetable fat	1.82	0.31	3.00
Limestone (or oyster shell)	0.49	0.81	8.66
Dicalcium phosphate	0.13	1.54	0.49
Salt	0.10	0.09	0.20
Sodium bicarbonate	0.20	0.20	0.20
Copper sulfate	0.05	0.05	-
Vitamin-mineral premix	0.25	0.25	0.25
DL-methionine (99%)	0.17	0.24	0.11
L-lysine HCl (78.4% lysine)	-	0.23	-
Bacitracin-MD (50 g/lb)'	0.05	0.05	-
Coban (monensin) 30 g/lb	-	0.10	-
Nicarbazin (25%)	0.05	-	-
Liquid mold inhibitor	0.05	0.05	-
Calculated analysis			
Protein, % (N x 6.25)	22.50	28.00	18.00
ME, kcal/lb	1425	1280	1320
Lysine, %	1.21	1.80	0.94
Methionine + cystine, %	0.92	1.10	0.71
Ca, %	0.95	1.45	3.80
Available P, %	0.48	0.83	0.45
Na,%	0.20	0.19	0.18
K, %	0.83	0.94	0.68
Cl,%	0.25	0.24	0.19

[a]CP = crude protein; ME = metabolizable energy; N = nitrogen.

MAJOR INGREDIENTS FOR POULTRY DIETS

1. **Selecting Feedstuffs - Considerations?**

A. Nutrient availability? - Affected by the fiber content, fat content, and amino acid balance.
B. Palatability? - Affected by the moisture content, contaminants, feed preparation (whole vs. ground), and color or light reflections.
C. The content of growth inhibitors or undesirable chemicals or pigments.
D. The cost and market availability of feedstuffs.

2. **Energy Sources**

A. Grains - Corn is the most important & widely used. Also, milo, wheat, barley, and oats are being used, but, perhaps, inferior to corn in the relative value.
B. Grain by-products - Including various milling by-products (e.g., corn gluten & bran, and wheat processing by-products), brewery by-products, etc.
C. Molasses - Used as a source of energy but have an adverse laxative effect, thus should be limited to not more than 2% of the diet.
D. Vegetable & animal fats - Used as energy sources, but also reduce feed dustiness, increase palatability, and improve texture and appearance of the feed.

3. **Protein/Amino Acid Sources**

A. Plant sources

1) Soybean meal - Most widely used because of its ability to provide indispensable amino acids; high in digestibility and low in toxic or undesirable substances.
2) Cottonseed meal:

1) Generally not used for layer diets because of: a) gossypol, which can cause a mottling and greenish cast to egg yolks, and b) cyclopropenoic fatty acids, which can impart a pink color to egg whites.
2) May be used to replace up to 50% of the soybean meal in grower poultry diets.

3) Linseed meal - Can use a limited amount but may depress growth and cause diarrhea. Should not exceed 3 to 5% of the poultry diet.
4) Alfalfa meal and corn gluten meal - Used extensively, both for their high content of carotenoids. Both should be limited to not more than 10%.

B. Animal sources

1) Fish meals - Often used at 2 to 5% of the diet, but high in fat & tend to create a fishy flavor in meat and eggs when used in larger amounts.
2) Meat products (animal by-products, poultry meal, blood meal, hydrolyzed poultry feather) - Often economically priced, thus may replace an equal amount of soybean meal protein up to about 10% of the diet. Excellent sources of Ca & P.

4. **Mineral Sources**

A. Ca - Common supplements are ground limestone, crushed oyster shells or oyster shell flour, bone meal, and dicalcium phosphate.
B. P - Common supplements are bone meal, dicalcium phosphate, deflourinated rock phosphate, monosodium phosphate, and rock phosphate.
C. Salt - Common to add 0.2 to 0.5%. Too much salt will result in increased water consumption and wet droppings.

5. **Vitamin Sources**

A. Unlike in the past, a wide variety of feedstuffs are not included in poultry diets for their vitamin content.
B. Vitamin premixes are commonly used to satisfy the vitamin needs.

6. **Diet Preparation**

A. Most poultry feeds are: 1) mash - grind medium to fine, 2) pellets - composed of mash feeds that are pelleted, and 3) crumbles - produced by rolling pellets.
B. Pellets or crumbles - Cost slightly more, but can reduce feed wastage & sorting, adapted to automatic equipment, less feeder and storage space, and improve palatability.

FEEDING PROGRAMS

1. **Broilers**

A. Broiler chicks - Fed ad libitum for 42 to 56 d to an average weight of 4 to 5 lb.
B. Feed represent 60 to 75% of total production cost. Fed conversion - about 2.0?
C. Use a 3-stage feeding program (starter, grower and finisher) - The starter for the first 2 to 3 wk, the grower for about 2 wk, and the finisher for the remainder.

2. **Replacement Pullets**

A. Generally divided into three stages:

1) Starter with 18-20% CP & about 3,000 kcal ME/kg from 0 to 6 wk of age.
2) Grower with 14-16% CP & about 3,000 kcal ME/kg from 6 to 12 wk of age.
3) Developer with 12 to 14% CP & about 3,000 kcal ME/kg from 12 wk of age until lay (approximately 20 wks).

B. Leghorn-type pullets - Seldom fed restrictedly during the growing period because feed intake & sexual maturity can be controlled by varying lighting during 6 to 20 wk of age.
C. Heavy breeds - Tend to deposit excess body fat, thus common to restrict feed:

1) Most effective program? - Feed daily a controlled amount of a well-balanced diet. Requires adequate feeder space and a rapid even distribution of the diet.

2) Alternative? - A skip-a-day feeding program. With adequate feeder and water space, may produce a more uniform flock.

D. When pullets start producing eggs, their feed intake should increase. Sometimes, necessary to reduce the energy density at 18 to 19 wk of age to increase feed intake.
E. Laying about five eggs per 1000 birds, the birds should be placed on a pre-lay program, in which the diet contains about 2% or more Ca.
F. 5% egg production? - Should be placed on a regular layer feed program.

3. **Laying Hens**

A. Higher concentrations of vitamins (A, D, E, riboflavin, pantothenic acid, niacin, and B_{12}) and Mn & Zn would be required if eggs are to be used for hatching.
B. White Leghorn - Need about 18 g of protein/bird/d to support optimum egg production, thus with a 15% CP diet, must consume ≈ 25 to 26 lb of feed/100 birds/day.
C. Met - The first limiting amino acid and economical to use synthetic Met & its analogs.
D. Ca, P, and Vitamin D - Important for egg shell formation?

1) Ca requirement - Varies with the age, ambient temperature, rate of lay, and egg size, but a general recommendation is 3.4 g Ca/d & 3.8 g Ca/d after 40 wk of age.
2) P? - 0.3 to 0.4% available P, which is equivalent to about 0.5 to 0.6% total P.
3) Adequate vitamin D_3 is must.

E. Grits - Can improve feed efficiency slightly, but not when finely ground feeds are fed. Can be fed in special feeders every 3 wk, mixed in a complete feed at 0.25% of the diet, or sprinkled on top of the feed at a rate of 5 lb per 1,000 hens every week.
F. Phase feeding - To reduce the waste of nutrients caused by feeding more than necessary:

1) Pullets coming into egg production - 17 to 19% CP and reduce to 15 to 16% after 3 to 4 mo of lay, or when the pullet has attained the adult weight.
2) Feed intake decreases as the temperature increases above 85 to 90°F, thus may be necessary to increase CP to 18 or 20% when temperature exceeds 100°F for an extended period of time.

G. Challenge the flock to lay more eggs?

1) Young pullet flocks may respond to additional feed when their production seems to be reaching a plateau.
2) "Challenge" the flock with about 2 more pounds of feed per 100 birds. If the flock does not respond by the 4th day, return to the amount fed prior to the challenge. Can be repeated as often as necessary depending on the flock response.

H. Peaked in egg production & begun a gradual decline in lay?

1) Sometimes, will produce more efficiently on less feed.
2) Passed peak & showing a normal decrease (4 to 6%)?

    a) Reducing the daily feed by ½ lb/100 birds for a period of 3-4 days. If results in an abnormal drop in egg production, return immediately to the prior feeding.
    b) As production continues to decline normally, this may be repeated as often as necessary depending on flock response.

I. The bottom line? The objective of feeding laying hens is to produce a dozen eggs of good quality at the lowest possible feed cost. For lightweight layers, a target should be a feed efficiency of 3.5 to 4.0 lb or less of feed/dozen eggs.

4. Feeding Turkeys

A. Marketing turkeys:

1) Change diets frequently to adjust to the specific needs and to minimize feed costs.
2) Grow faster than chickens, thus have relatively higher requirements:

    a) Protein requirements decrease by age, e.g., 28% with starting poults to 14% for mature birds.
    b) Energy requirements tend to increase during the growing stage; ranging from 2,900 to 3,300 kcal/kg.

3) Upon arrival, poults should be encouraged to consume feed and water as soon as possible. Using colored feed or placing brightly colored marbles in the feed and water may help.
4) Antibiotic & coccidiostat? - May be necessary for early starter diets but once past 8 to 12 wk of age, may be optional!
5) Young turkeys - Should be about 2.75 to 3.25 lb of feed/lb live turkey produced.
6) Marketing?

    a) Males/toms - 18 to 20 wk of age & 23 to 35 lb live weight. Younger toms for oven-ready dressed birds & older toms for further processing or restaurant trade.
    b) Females/hens - 14 to 16 wk of age and about 14 lb live weight.

B. Holding and breeding:

1) Feed a "holding diet" from ≈ 16 to 18 wk of age until the beginning of the lighting program (≈2 wk before egg production), which usually occurs about 30 wk of age.
2) "Holding diet?" - Contains less energy than the starter and grower diets & delays sexual maturity, which may result in desirable effects on later reproductive performance.
3) After 30 wk or so of age? Should feed the breeder diet.

NUTRIENT REQUIREMENT TABLES
(Based on NRC, 1994)

1. Table 1. DIETARY Nutrient Requirements of Immature Leghorn-Type Chickens (% or Unit/kg; 90% DM?)

		White-Egg-Laying Strains				Brown-Egg-Laying Strains			
Weeks:		0 to 6	6 to 12	12 to 18	18 to 1st Egg	0 to 6	6 to 12	12 to 18	18 to 1st Egg
Final Body Weight, g:		450	980	1,375	1,475	500	1,100	1,500	1,600
Typical dietary Energy, ME_n/kg:		2,850	2,850	2,900	2,900	2,800	2,800	2,850	2,850
Protein and amino acids:									
Crude protien[a]	%	18.00	16.00	15.00	17.00	17.00	15.00	14.00	16.00
Arginine	%	1.00	0.83	0.67	0.75	0.94	0.78	0.62	0.72
Glycine + serine	%	0.70	0.58	0.47	0.53	0.66	0.54	0.44	0.50
Histidine	%	0.26	0.22	0.17	0.20	0.25	0.21	0.16	0.18
Isoleucine	%	0.60	0.50	0.40	0.45	0.57	0.47	0.37	0.42
Leucine	%	1.10	0.85	0.70	0.80	1.00	0.80	0.65	0.75
Lysine	%	0.85	0.60	0.45	0.52	0.80	0.56	0.42	0.49
Methionine	%	0.30	0.25	0.20	0.22	0.28	0.23	0.19	0.21
Methionine + cystine	%	0.62	0.52	0.42	0.47	0.59	0.49	0.39	0.44
Phenylalanine	%	0.54	0.45	0.36	0.40	0.51	0.42	0.34	0.38
Phenylalanine + tyrosine	%	1.00	0.83	0.67	0.75	0.94	0.78	0.63	0.70
Threonine	%	0.68	0.57	0.37	0.47	0.64	0.53	0.35	0.44
Tryptophan	%	0.17	0.14	0.11	0.12	0.16	0.13	0.10	0.11
Valine	%	0.90	0.80	0.80	2.00	0.90	0.80	0.80	1.80
Linoleic acid:	%	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Macrominerals:									
Calcium[b]	%	0.90	0.80	0.80	2.00	0.90	0.80	0.80	1.80
Nonphytate phosphorus	%	0.40	0.35	0.30	0.32	0.40	0.35	0.30	0.35
Potassium	%	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25
Sodium	%	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15
Chlorine	%	0.15	0.12	0.12	0.15	0.12	0.11	0.11	0.11
Magnesium	mg	600.0	500.0	400.0	400.0	570.0	470.0	370.0	370.0
Trace minerals:									
Manganese	mg	60.0	30.0	30.0	30.0	56.0	28.0	28.0	28.0
Zinc	mg	40.0	35.0	35.0	35.0	38.0	33.0	33.0	33.0
Iron	mg	80.0	60.0	60.0	60.0	75.0	56.0	56.0	56.0
Copper	mg	5.0	4.0	4.0	4.0	5.0	4.0	4.0	4.0
Iodine	mg	0.35	0.35	0.35	0.35	0.33	0.33	0.33	0.33
Selenium	mg	0.15	0.10	0.10	0.10	0.14	0.10	0.10	0.10
Fat-soluble vitamins:									
Vitamin A	IU	1,500.0	1,500.0	1,500.0	1,500.0	1,420.0	1,420.0	1,420.0	1,420.0
Vitamin D_3	ICU	200.0	200.0	200.0	300.0	190.0	190.0	190.0	280.0
Vitamin E	IU	10.0	5.0	5.0	5.0	9.5	4.7	4.7	4.7
Vitamin K	mg	0.50	0.50	0.50	0.50	0.47	0.47	0.47	0.47
Water-soluble vitamins:									
Riboflavin	mg	3.6	1.8	1.8	2.2	3.4	1.7	1.7	1.7
Pantothenic acid	mg	10.0	10.0	10.0	10.0	9.4	9.4	9.4	9.4
Niacin	mg	27.0	11.0	11.0	11.0	26.0	10.3	10.3	10.3
Vitamin B_{12}	mg	0.009	0.003	0.003	0.003	0.009	0.003	0.003	0.003
Choline	mg	1,300.0	900.0	500.0	500.0	1,225.0	850.0	470.0	470.0
Biotin	mg	0.15	0.10	0.10	0.10	0.14	0.09	0.09	0.09
Folic acid	mg	0.55	0.25	0.25	0.25	0.52	0.23	0.23	0.23
Thiamin	mg	1.0	1.0	0.8	0.8	1.0	1.0	0.8	0.8
Pyridoxine	mg	3.0	3.0	3.0	3.0	2.8	2.8	2.8	2.8

☞ Some experimental data are lacking, thus some values represent an estimate based on values obtained for other ages or related species (NRC, 1994).

[a]Chickens do not have a requirement for crude protein per se. There, however, should be sufficient crude protein to ensure an adequate nitrogen supply for synthesis of nonessential amino acids. Suggested requirements for crude protein are typical of those derived with corn-soybean meal diets, and levels can be reduced somewhat when synthetic-amino acids are used.

[b]The calcium requirement may be increased when diets contain high levels of phytate phosphorus (Nelson, 1984).

2. Table 2. DIETARY Nutrient Requirements of Leghom-Type Laying Hens (% or Unit/kg; 90% DM)

		Dietary Concentrations			Amounts Required per Hen Daily (mg or IU)		
Type:		White-Egg Layers	White-Egg Layers	White-Egg Layers	White-Egg Breeders	White-Egg Layers	Brown-Egg Layers
Feed intake, g/hen/day[a]:		80	100	120	100	100	110
Protein and amino acids:							
Crude protein[b]	%	18.8	15.0	12.5	15,000	15,000	16,500
Arginine[c]	%	0.88	0.70	0.58	700	700	770
Histidine	%	0.21	0.17	0.14	170	170	190
Isoleucine	%	0.81	0.65	0.54	650	650	715
Leucine	%	1.03	0.82	0.68	820	820	900
Lysine	%	0.86	0.69	0.58	690	690	760
Methionine	%	0.38	0.30	0.25	300	300	330
Methionine + cystine	%	0.73	0.58	0.48	580	580	645
Phenylalanine	%	0.59	0.47	0.39	470	470	520
Phenylalanine + tyrosine	%	1.04	0.83	0.69	830	830	910
Threonine	%	0.59	0.47	0.39	470	470	520
Tryptophan	%	0.20	0.16	0.13	160	160	175
Valine	%	0.88	0.70	0.58	700	700	770
Linoleic acid:	%	1.25	1.00	0.83	1,00	1,00	1,00
Macrominerals:							
Calcium[d]	%	4.06	3.25	2.71	3,250	3,250	3,600
Chloride	%	0.16	0.13	0.11	130	130	145
Magnesium	mg	625	500	420	50	50	55
Nonphytate phosphorus[e]	%	0.31	0.25	0.21	250	250	275
Potassium	%	0.19	0.15	0.13	150	150	165
Sodium	%	0.19	0.15	0.13	150	150	165
Trace minerals:							
Copper	mg	?	?	?	?	?	?
Iodine	mg	0.044	0.035	0.029	0.010	0.004	0.004
Iron	mg	56	45	38	6.0	4.5	5.0
Manganese	mg	25	20	17	2.0	2.0	2.2
Selenium	mg	0.08	0.06	0.05	0.006	0.006	0.006
Zinc	mg	44.0	35.0	29.0	4.5	3.5	3.9
Fat-soluble vitamins:							
Vitamin A	IU	3,750	3,000	2,500	300	300	330
Vitamin D_3	ICU	375	300	250	30	30	33
Vitamin E	IU	6.00	5.00	4.00	1.00	0.50	0.55
Vitamin K	mg	0.60	0.50	0.40	0.10	0.05	0.055
Water-soluble vitamins:							
Vitamin B_{12}	mg	0.004	0.004	0.004	0.008	0.0004	0.00004
Biotin	mg	0.13	0.10	0.08	0.01	0.01	0.011
Choline	mg	1,310	1,050	875	105	105	115
Folic acid	mg	0.31	0.25	0.21	0.035	0.025	0.028
Niacin	mg	12.50	10.00	8.30	1.00	1.00	1.10
Pantothenic acid	mg	2.50	2.00	1.70	0.70	0.20	0.22
Pyridoxine	mg	3.10	2.50	2.10	0.45	0.25	0.28
Riboflavin	mg	3.10	2.50	2.10	0.36	0.25	0.28
Thiamin	mg	0.88	0.70	0.60	0.07	0.07	0.08

☞ Some experimental data are lacking, thus some values represent an estimate based on values obtained for other ages or related species (NRC, 1994).

[a]Based on dietary MEn concentrations of approximately 2,900 kcal/kg and an assumed rate of egg production of 90 percent (90 eggs per 100 hens daily).

[b]Laying hens do not have a requirement for crude protein per se. However, there should be sufficient crude protein to ensure an adequate supply of nonessential amino acids. Suggested requirements for crude protein are typical of those derived with corn-soybean meal diets, and levels can be reduced somewhat when synthetic amino acids are used.

[c]Italicized amino acid values for white-egg-laying chickens were estimated by using Model B (Hurwitz and Bomstein, 1973), assuming a body weight of 1,800 g and 47 g of egg mass per day.

[d]The requirement may be higher for maximum eggshell thickness.

[e]The requirement may be higher in very hot temperatures.

3. Table 3. DIETARY Nutrient Requirements of Broilers (% or Unit/kg; 90% DM)

Week[a]:		0 to 3	3 to 6	6 to 8
Typical dietary energy, ME_n/kg		3,200	3,200	3,200
Protein and amino acids:				
Crude protein[b]	%	23.00	20.00	18.00
Arginine	%	1.25	1.10	1.00
Glycine + Serine	%	1.25	1.14	0.97
Histidine	%	0.35	0.32	0.27
Isoleucine	%	0.80	0.73	0.62
Leucine	%	1.20	1.09	0.93
Lysine	%	1.10	1.00	0.85
Methionine	%	0.50	0.38	0.32
Methionine + cystine	%	0.90	0.72	0.60
Phenylalanine	%	0.72	0.65	0.56
Phenylalanine + tyrosine	%	1.34	1.22	1.04
Threonine	%	0.80	0.74	0.68
Tryptophan	%	0.20	0.18	0.16
Valine	%	0.90	0.82	0.70
Linoleic acid:	%	1.00	1.00	1.00
Macrominerals:				
Calcium[c]	%	1.00	0.90	0.80
Chloride	%	0.20	0.15	0.12
Magnesium	mg	600	600	600
Nonphytate phosphorus[e]	%	0.45	0.35	0.30
Potassium	%	0.30	0.30	0.30
Sodium	%	0.20	0.15	0.12
Trace minerals:				
Copper	mg	8	8	8
Iodine	mg	0.35	0.35	0.35
Iron	mg	80	80	80
Manganese	mg	60	60	60
Selenium	mg	0.15	0.15	0.15
Zinc	mg	40	40	40
Fat-soluble vitamins:				
Vitamin A	IU	1,500	1,500	1,500
Vitamin D_3	ICU	200	200	200
Vitamin E	IU	10	10	10
Vitamin K	mg	0.50	0.50	0.50
Water-soluble vitamins:				
Vitamin B_{12}	mg	0.01	0.01	0.007
Biotin	mg	0.15	0.15	0.12
Choline	mg	1,300	1,000	750
Folic acid	mg	0.55	0.55	0.50
Niacin	mg	35	30	25
Pantothenic acid	mg	10	10	10
Pyridoxine	mg	3.5	3.5	3.0
Riboflavin	mg	3.6	3.6	3.0
Thiamin	mg	1.80	1.80	1.80

☞ Some experimental data are lacking, thus some values represent an estimate based on values obtained for other ages or related species (NRC, 1994).

[a]0 to 3, 3 to 6, and 6 to 8 week intervals for nutrient requirements are based on chronology for which data were available; hoever, these nutrient requirements are often implemented at younger age intervals or on a weight-of-feed consumed basis.

[b]Broiler chickens do not have a requirement for crude protein per se. However, there should be sufficient crude protein to ensure an adequate supply of nonessential amino acids. Suggested requirements for crude protein are typical of those derived with corn-soybean meal diets, and levels can be reduced somewhat when synthetic amino acids are used.

[c]The calcium requirement may be increased when diets contain high levels of phytate phosphorus (Nelson,1984).

4. Table 4. Body Weight and Feed Consumption of Immature Leghorn-Type Chickens[a]

Age (wk)	White-Egg-Laying Strains		Brown-Egg-Laying Strains	
	Body Weight (g)	Feed intake (g/wk)	Body Weight (g)	Feed Intake (g/wk)
0	35	50	37	70
2	100	140	120	160
4	260	260	325	280
6	450	340	500	350
8	660	360	750	380
10	750	380	900	400
12	980	400	1,100	420
14	1,100	420	1,240	450
16	1,220	430	1,380	470
18	1,375	450	1,500	500
20	1,475	500	1,600	550

[a]Average genetic potential when feed is consumed on an ad libitum basis. Different commercial strains may show different growth rates and different final mature body weights.

5. Table 5. Estimates of Metabolizable Energy Required per Hen per Day by Chickens in Relation to Body Weight and Egg Production (kcal)

Body Weight (kg)	Rate of Egg Production (%)					
	0	50	60	70	80	90
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

☞ 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): ME per hen daily = $W^{0.75}$ (173 -1.95T) + 5.5 $\triangle$W + 2.07 EE where W = body weight (kg), T = ambient temperature (°C), $\triangle$W = change in body weight (g/day), and EE = daily egg mass (g). Temperature of 22°C, egg weight of 60 g, and no change in body weight were used in calculations.

6. Table 6. Typical Body Weights, Feed Intake, and Energy Intake of Broilers

Age (wk)	Body Weight (g)		Feed Intake (g)				Energy Intake (kcal ME/bird)			
			Weekly		Cumulative		Weekly		Cumulative	
	Male	Female	Male	Female	Male	Female	Male	Female	Male	Female
1	152	144	135	131	135	131	432	419	432	419
2	376	344	290	273	425	404	928	874	1,360	1,293
3	686	617	487	444	912	848	1,558	1,422	2,918	2,715
4	1,085	965	704	642	1,616	1,490	2,256	2,056	5,174	4,771
5	1,576	1,344	960	738	2,576	2,228	3,075	2,519	8,249	7,290
6	2,088	1,741	1,141	1,001	3,717	3,229	3,651	3,045	11,900	10,335
7	2,590	2,134	1,281	1,081	4,998	4,310	4,102	3,459	16,002	13,794
8	3,077	2,506	1,432	1,165	6,430	5,475	4,585	3,728	20,587	17,522
9	3,551	2,842	1,577	1,246	8,007	6,721	5,049	3,986	25,636	21,508

☞ Values are typical broilers fed well-balanced diets providing 3,200 kcal ME/kg.

7. Table 7. DIETARY Nutrient Requirements of Turkeys (% or Unit/kg; 90% DM)

		Growing Turkeys						Breeders	
Males - Age (wk):		0 to 4	4 to 8	8 to 12	12 to 16	16 to 20	20 to 24		
Females - Age (wk):		0 to 4	4 to 8	8 to 11	11 to 14	14 to 17	17 to 20		
Status: Holding Laying								Holding	Laying
Dietary energy, ME_n/kg[a]:		2,800	2,900	3,000	3,100	3,200	3,300	2,900	2,900
Protein and amino acids:									
Protein[b]	%	28.0	26.0	22.0	19.0	16.5	14.0	12.0	14
Arginine	%	1.60	1.40	1.10	0.90	0.75	0.60	0.50	0.60
Glycine + serine	%	1.00	0.90	0.80	0.70	0.60	0.50	0.40	0.50
Histidine	%	0.58	0.50	0.40	0.30	0.25	0.20	0.20	0.30
Isoleucine	%	1.10	1.00	0.80	0.60	0.50	0.45	0.40	0.50
Leucine	%	1.90	1.75	1.50	1.25	1.00	0.80	0.50	0.50
Lysine	%	1.60	1.50	1.30	1.00	0.80	0.65	0.50	0.60
Methionine	%	0.55	0.45	0.40	0.35	0.25	0.25	0.20	0.20
Methionine + cystine	%	1.05	0.95	0.80	0.65	0.55	0.45	0.40	0.40
Phenylalanine	%	1.00	0.90	0.80	0.70	0.60	0.50	0.40	0.55
Phenylalanine + tyrosine	%	1.80	1.60	1.20	1.00	0.90	0.90	0.80	1.00
Threonine	%	1.00	0.95	0.80	0.75	0.60	0.50	0.40	0.45
Tryptophan	%	0.26	0.24	0.20	0.18	0.15	0.13	0.10	0.13
Valine	%	1.20	1.10	0.90	0.80	0.70	0.60	0.50	0.58
Linoleic acd:	%	1.00	1.00	0.80	0.80	0.8	0.8	0.8	1.1
Macrominerals:									
Calcium[c]	%	1.20	1.00	0.85	0.75	0.65	0.55	0.5	2.25
Nonphytate phosphorus[d]	%	0.60	0.50	0.42	0.38	0.32	0.28	0.25	0.35
Potassium	%	0.70	0.60	0.50	0.50	0.40	0.40	0.40	0.60
Sodium	%	0.17	0.15	0.12	0.12	0.12	0.12	0.12	0.12
Chlorine	%	0.15	0.14	0.14	0.12	0.12	0.12	0.12	0.12
Magnesium	mg	500	500	500	500	500	500	500	500
Trace minerals:									
Manganese	mg	60	60	60	60	60	60	60	60
Zinc	mg	70	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	0.40	0.40	0.40	0.40	0.40	0.40	0.40	0.40
Selenium	mg	0.20	0.20	0.20	0.20	0.20	0.20	0.20	0.20
Fat-soluble vitamins:									
Vitamin A	IU	5,000	5,000	5,000	5,000	5,000	5,000	5,000	5,000
Vitamin D_3[c]	ICU	1,100	1,100	1,100	1,100	1,100	1,100	1,100	1,100
Vitamin E	IU	12	12	10	10	10	10	10	25
Vitamin K	mg	1.75	1.50	1.00	0.75	0.75	0.50	0.50	1.00
Water-soluble vitamins:									
Vitamin B_{12}	mg	0.003	0.003	0.003	0.003	0.003	0.003	0.003	0.003
Biotin[f]	mg	0.250	0.200	0.125	0.125	0.100	0.100	0.100	0.200
Choline	mg	1,600	1,400	1,100	1,000	950	800	800	1,000
Folacin	mg	1.00	1.00	0.80	0.80	0.70	0.70	0.70	1.00
Niacin	mg	60.0	60.0	50.0	50.0	40.0	40.0	40.0	40.0
Pantothenic acid	mg	10.00	9.00	9.00	9.00	9.00	9.00	9.00	16.00
Pyridoxine	mg	4.50	4.50	3.50	3.50	3.00	3.00	3.00	4.00
Riboflavin	mg	4.00	3.60	3.00	3.00	2.50	2.50	2.50	4.00
Thiamin	mg	2.00	2.00	2.00	2.00	2.00	2.00	2.00	2.00

☞NOTE Where experimental data are lacking, values typeset in bold italics represent estimates based on valued obtained from other ages or relate species or from modeling experiments. Also, genetic improvements in body weight gain have led to an "earlier implementation" of those requirements (e.g., males - 0-3, 3-6, 6-9, 9-12, 12-15, and 15-18 wk & females - 0-3, 3-6, 6-9, 9-12, 12-14, and 14-16 wk) by the industry at large.

[a]These are approximate metabolizable energy (ME) values provided with typical corn-soybean-meal-based feeds, expressed in kcal MEn/kg diet. Such energy, when accompanied by the nutrient levels suggested, is expected to provide near-maximum growth, particularly with pelleted feed.

[b]Turkeys do not have a requirement for crude protein per se. There, however, should be sufficient crude protein to ensure an adequate nitrogen supply for synthesis of noness ential amino acids. Suggested requirements for crude protein are typical of those derived with corn-soybean meal diets, and levels can be reduced when synthetic amino acids are used. .

[c]The calcium requirement may be increased when diets contain high levels of phytate phosphorus (Nelson, 1984).

[d]Organic phosphorus is generally considered to be associated with phytin and of limited availability.

[e]These concentrations of vitamin Dare considered satisfactory when the associated calcium and phoxphorus levels are used.

[f]Requirement may increase with wheat-based diets.

8. Table 8. Growth Rate, Feed Intake, and Energy Intake in Large-Type Turkeys

	Body Weight (kg)		Feed Intake, per week (kg)		Feed Intake, Cumulative (kg)		ME Intake, Cumulative (Mcal)	
Age (wk)	Male	Female	Male	Female	Male	Female	Male	Female
1	0.12	0.12	0.10	0.10	0.10	0.10	0.28	0.28
2	0.25	0.24	0.19	0.18	0.29	0.28	0.53	0.5
3	0.50	0.46	0.37	0.34	0.66	0.62	1.0	1.0
4	1.00	0.90	0.70	0.59	1.36	1.21	2.0	1.7
5	1.60	1.40	0.85	0.64	2.21	1.85	2.5	1.9
6	2.20	1.80	1.10	0.80	3.31	2.65	3.2	2.3
7	3.10	2.30	1.40	0.98	4.71	3.63	4.1	2.8
8	4.00	3.00	1.73	1.21	6.44	4.84	5.0	3.5
9	5.00	3.70	2.00	1.42	8.44	6.26	6.0	4.3
10	6.00	4.40	2.34	1.70	10.78	7.96	7.0	5.1
11	7.10	5.20	2.67	1.98	13.45	9.94	8.0	5.9
12	8.20	6.00	2.99	2.18	16.44	12.12	9.0	6.8
13	9.30	6.80	3.20	2.44	19.64	14.56	9.9	7.6
14	10.50	7.50	3.47	2.69	23.11	17.25	10.8	8.4
15	11.50	8.30	3.73	2.81	26.84	20.06	11.6	9.0
16	12.60	8.90	3.97	3.00	10.81	23.06	12.3	9.6
17	13.50	9.60	4.08	3.14	34.89	26.20	13.1	10.1
18	14.40	10.20	4.30	3.18	39.19	29.38	13.8	10.5
19	15.20	10.90	4.52	3.31	43.71	32.69	14.5	10.9
20	16.10	11.50	4.74	3.40	48.45	36.09	15.2	11.2
21	17.00	-	4.81	-	53.26	-	15.9	-
22	17.90	-	5.00	-	58.26	-	16.5	-
23	18.60	-	5.15	-	63.41	-	17.1	-
24	19.40	-	5.28	-	68.69	-	17.4	-

(-) No data given because females are usually not marketed after 20 weeks of age.