Nutrition & Health: Poultry

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THERE is a wealth of information available on alternative feeding programs for broilers, layers and turkeys, the basis of which has always been the various National Research Council (NRC) publications. The most recent such publication is *Nutrient Requirements of Poultry*, Ninth Revised Edition, released in 1994, and so unfortunately this information is now 17 years old, which is a considerable time period considering the continual improvement in genetic potential of and meat birds and especially the changes seen in egg layers.

Nutritionists invariably criticize these NRC recommendations as not representing the needs of poultry housed and managed under commercial conditions, which is a situation reflecting local knowledge that influences their specific farm operations. On the other hand, as feed costs increase, there is an interesting trend back towards these lower levels of nutrients as recommended by NRC (1994).

Limitations of NRC estimates

The NRC species subcommittees are given one straightforward although somewhat restrictive mandate to base nutrient recommendations only on data from peer-reviewed journals. This directive is particularly restrictive to estimating certain nutrient needs, since there has been a lack of scientific research and publication on many nutrients over the last 40 years. This situation dictates the reliance on somewhat dated literature estimates of certain nutrient needs. On the other hand, everyone recognizes the increase in growth rate of broilers and turkeys that has occurred over the last 40 years and the increased egg output of modern layer strains. Another concern is that many of the older research studies involved purified diets that often contained isolated soybean protein or casein as a source of protein and amino acids and dextrose, starch and sucrose as a source of energy. Cellulose was often used as non-nutritive filler in these purified diets. Such diets are highly digestible and are not encumbered with facets of variable nutrient availability and so can be criticized as not being of relevance to commercial feeding.

Perhaps more important, there has been a gradual change in our assessment criteria in defining nutrient needs relative to those used in most publications used in NRC(1994). Virtually all nutrient needs for broilers were assessed by NRC in terms of growth rate and perhaps feed utilization. For layers, the criteria are simply egg production, eggshell quality and egg weight. For the broiler chicken, the needs for lysine now relate to not only growth and feed utilization but also breast meat yield and carcass quality. Broiler chickens today are marketed over a vast range of weights/ages and, in some instances, these may be as mixed-sex or separate-sex flocks. Yet another major change has been the move to controlled-environment housing that, in itself, affects the birds' nutrient needs and growth potential. Of late, there has been the impetus to consider manure loading of nutrients during formulation of most poultry diets and, in the future, perhaps gaseous losses including ammonia from poultry farms.

An interesting scenario has occurred with broilers over the last 20 years or so, and that highlights the importance of the continual need for reappraisal of feeding systems. In the mid-1990s, metabolic disorders such as ascites, sudden death syndrome and leg disorders together accounted for 3-8% of mortality in male broilers. In order to counteract such problems, it was common to feed lower nutrient-dense diets or even mash diets, at least for part of the grow-out period. Today, such disorders are much less problematic due to genetic selection, and consequently, there is little need for any period of under-nutrition. Consequently, over a 15-year period, we have gone from a situation of selecting nutrients for maximum growth followed by a 5- to 6-year period of consideration for tempering growth, back to today's goal of maximum growth rate.

For egg production, we no longer have the luxury of formulating solely for egg number, which is the basis for most classical nutrient values. There is now an interest in egg composition, both in terms of nutrient profile as it affects human nutrition, as well as component/solid yield for egg processing. There has always been concern about optimizing eggshell quality, and this becomes more critical today with white-egg strains capable of producing 335 eggs in 365 days within reasonably large commercial flocks. The current trend of maintaining layers at 24-26°C in modern housing systems imposes a fairly predictable limit to feed intake and so allows for greater precision in selection of diet nutrient levels.

These evolving on-farm conditions, together with advances in feed processing, mean that nutritionists cannot expect published nutrient values, from whatever source, to be applicable to feeding birds under all commercial conditions. Likewise many published nutrient requirement specifications are "world-wide" and as such carry considerable safety margins for those practicing good manufacturing practices (GMP).

The productivity of poultry is ultimately governed by the bird's daily feed intake. We can formulate diets with various levels of nutrient density, yet unless the bird eats to expectation, productivity will suffer. Today, the best example of this confounding effect is the influence of broiler stocking density on flock performance, where the ability of the bird to physically eat sufficient feed dictates growth rate and feed utilization. In many flocks there is unintentional feed restriction after about 28d, because broilers simply don't have sufficient time to physically eat feed, especially in situations of reduced day length combined with sub-optimal pellet quality

Ingredient evaluation

The nutritionist's main goal is to define the bird's requirements, define the content of these same nutrients within ingredients and then to integrate these two data sets in the form of a least-cost formulation. In this instance, "least-cost" refers to the minimal cost to achieve the diet specifications rather than the lowest possible cost to produce a kilo of meat or a dozen eggs.

We still have major limitations regarding accurate information on the nutrient profile of ingredients used to make feed at a specific point in time. At best, our quality control procedures provide us with information on crude estimates of the ingredient nutrient profile, since the assay of individual nutrients is time consuming and at best provides us with an historical database. Of all the nutrients in a diet, the most expensive and the most critical to bird performance are energy and the essential amino acids. Neither of these can be assayed in real time with any great degree of precision. Methodologies such as near infrared analysis (NIRA) allow for reasonable estimates of real-time

1. Estimation of amino acids from crude protein content of common feed ingredients[1,2]

Ingredient	DM, %	CP, %	Regression factor	Met.	Met. + Cys.	Lys.	Thr.	Trp.	Arg.
Alfalfa meal	88	16.3	A	-0.079	-0.052	0.013	-0.041	0.002	-0.119
			B	0.0191	0.0282	0.0410	0.0436	0.0138	0.0474
Corn	88	8.5	A	0.015	0.073	0.057	0.014	0.041	0.091
			B	0.0192	0.0345	0.0224	0.0336	0.0026	0.0353
Milo	88	9.0	A	0.038	0.084	0.094	0.029	0.004	0.089
			B	0.0135	0.0276	0.0121	0.0296	0.0103	0.0286
Barley	88	10.7	A	0.024	0.051	0.109	0.072	0.015	0.033
			B	0.0141	0.0328	0.0256	0.0266	0.0104	0.0438
Wheat	88	12.9	A	-0.009	0.042	0.094	0.026	0.307	0.022
			B	0.0163	0.0343	0.0194	0.0264	0.0087	0.0445
Wheat bran	88	15.4	A	-0.087	-0.034	0.0070	-0.206	—	0.020
			B	0.0208	0.0738	0.0353	0.0340	—	0.0649
Rice bran	88	12.6	A	-0.044	-0.001	0.011	0.051	—	0.40
			B	0.0241	0.0423	0.0466	0.0366	—	0.1112
Canola meal	88	34.8	A	0.177	0.140	1.133	0.25	0.081	0.510
			B	0.057	0.0419	0.0231	0.0377	0.0105	0.0499
Soybean meal	88	45.8	A	0.127	0.157	-0.252	0.203	-0.041	-0.543
			B	0.0111	0.0255	0.0665	0.0344	0.0144	0.0844
Sunflower meal	88	33.0	A	-0.107	-0.048	0.259	-0.051	-0.055	-0.559
			B	0.0255	0.0419	0.0265	0.0380	0.0134	0.0965
Fish meal	91	63.8	A	-0.909	-10.059	-2.706	-10.083	-0.492	-0.456
			B	0.042	0.054	0.1181	0.0588	0.0184	0.0652
Meat and bone meal	91	47.9	A	-0.416	-0.96	-0.867	-0.822	-0.405	0.773
			B	0.0215	0.0423	0.0671	0.0483	0.0139	0.0539
Poultry byproduct meal	91	58.4	A	-0.743	—	-3.221	1.158	—	-1.263
			B	0.0291	—	0.1057	0.0184	—	0.0879

[1]To estimate amino acid content, fit the equation y=a+bx, where x is the level of crude protein in the sample, a is the intercept and b is the regression coefficient.

[2]Adapted from National Research Council (1994).

analyses, yet results are subject to quite high variance on a sample-to-sample basis. The most expensive nutrient, namely energy, is very difficult to assay. This current limitation is even more problematic today since we rely most commonly on digestible or available nutrients rather than total levels within ingredients and diets. It is difficult to attain real-time analyses of soybean meal being used "today" at a feed mill and very difficult, if not impossible, to attain such data for digestible amino acids. There is a dire need for the poultry industry to fund a research program aimed at providing real-time analyses of energy and other available nutrients. NRC (1994, Table 1) and various commercial companies provide options for such analyses in the form of regression prediction of important amino acids based on crude protein content.

The amino acid needs of poultry are now invariably expressed in terms of digestible amino acids. Such values are usually determined using a force-feeding technique similar to that developed for true metabolizable energy (TME). Criticisms of such values are that they are determined with adult roosters and that digestibility is usually derived from feeding the ingredient in isolation. Digestibility by birds much less than 10 days of age is likely less than that determined with roosters. Table 2 outlines digestibility values for amino acids in some of the commonly used ingredients.

Metabolizable energy is currently the system of choice for comparing ingredients and defining the bird's requirements. A refinement of this concept is the formulation of diets and the definition of requirements in terms of net energy (NE). While NE will more adequately describe the available energy within an ingredient, it is even more difficult to assay than is AME. NE is classically determined using indirect calorimetry that involves measurement of gaseous exchange. Determination of NE of an ingredient will take some two to three months, and so it is of limited use in routine screening of ingredients. There has been an attempt at defining NE as the product of proximate components such as protein, starch and fat and their coefficients for digestibility. For example, the quantity of digestible fat is multiplied by its energy contribution. Defining digestibility is the key to success of the system. The limitations of this current NE system are that it is often based on book values for digestibility of nutrients and does not take into account the end use of the available energy. For example, NE of fat is greater if dietary fat is incorporated directly into body fat rather than being used as a source of maintenance energy, and this refinement is currently not incorporated into most NE systems of ingredient evaluation.

Vitamins and minerals

Vitamins have become very expensive over the last few years, and so nutritionists today often question the published requirement values. Table 3 outlines the vitamin and trace mineral needs of most classes of poultry. It is becoming more common to include both vitamins and minerals together within a single premix. Traditionally, the two components have been added as separate premixes due to the fact that mineral oxides can lead to the destruction of some vitamins. With today's more stable vitamins, and where premixes are not stored for more than four to six weeks, a combined premix is practical.

Depending upon usage rate, the premix will contain a carrier as the major component. For vitamin premixes, the carrier is often finely ground wheat shorts or limestone, while mineral premixes often utilize limestone as an inert carrier. The inclusion level of premixes has declined over time, since the carrier often adds few nutrients, and "space" within a formulation is of economic significance. Inclusion rates are usually 0.5-1.0 kg/metric ton.

Table 3 shows a requirement for supplemental choline. Choline is needed in relatively large quantities compared to the other vitamins, and it is also very hygroscopic. For this reason, choline is usually added as a separate ingredient and not included in premixes.

Vitamin D3 is the only form of the product to be used in poultry diets, since birds cannot metabolize vitamin D2. Thiamin, folic acid, pyridoxine and some vitamin K supplements can be relatively unstable in the presence of trace mineral supplements. This is especially true where the minerals are supplied as sulfates, hence special consideration must be given to these vitamins when premixes contain both vitamins and minerals and storage is for four to six weeks. Most of the other vitamins are fairly stable. While vitamin supplements are an extremely important part of a well-balanced diet, poultry usually have sufficient body stores to meet their requirements for several days, and especially for the fat-soluble vitamins.

Commercial poultry farms receive feed deliveries on a weekly or even more frequent basis. Failure to incorporate the vitamin premix in a delivery of feed will likely have little effect on the performance of most classes of poultry, assuming the "next delivery" contains the vitamin supplement. For breeding birds, this may not be true, especially for riboflavin, which could well affect hatchability if hens are fed a deficient diet for three to five days.

There is now considerable interest in use of organic minerals. These minerals are complexed with amino acids, peptides, proteins or organic acids. Although more expensive than inorganic salts, they should theoretically have better purity and so can be used with greater confidence at much lower levels in an attempt at limiting mineral accumulation in manure. Their greater degree of purity also gives greater confidence in meeting ever stricter guidelines for heavy metal contaminants such as arsenic and cadmium. Organic selenium has been used successfully for many years, and other organic trace minerals will likely gain favor as environmental regulations are imposed regarding excretion rates.

Ingredient prices

Over the last six months, there has been unprecedented fluctuation in ingredient prices with a trend to ever increasing prices on corn, fat and soybean meal. The reason for this upward spiral is multi-faceted, yet predictions are for record high commodity prices in the near future. With high feed prices, there is invariably discussion about reducing feed nutrient density, so as to limit increase in feed prices. However, layers, broilers and turkeys all eat to their energy requirements, and so this decision invariably results in increased feed intake and associated decline in numeric feed efficiency. Classically, there will be increased profitability if lower nutrient-dense ingredients (relative to corn or wheat) are priced at less per unit of energy than is corn/fat. One interesting advantage to lower nutrient density in broilers and turkeys is usually improved pellet quality, which itself offsets the usual decline in feed efficiency.

We are going to see an increase in the range of nutrient density used in poultry diets, and especially for broilers. For this reason, the following feeding specifications for broilers are expressed per unit of energy, so allowing for flexibility in diet formulations.

Broiler chickens

Diet specifications for broilers are detailed in Table 4. Units are expressed per 1,000 kcal ME since there is expectation for future fluctuations in energy density used in broiler production. Likewise, as feed prices escalate, the need to sustain efficiency may well lead to greater emphasis on separate sex rearing, where advantages of feed utilization are well recognized, especially for broilers heavier than 2.2 kg liveweight. Tables 5 and 6 provide examples of feeding schedules for male and female broilers using the diets detailed in Table 4 as a reference.

2. True digestibility coefficients (%) for selected amino acids in poultry feedstuffs[1]

Ingredient	CP	Lys.	Met.	Cys.	Arg.	Thr.	Val.	Ile.	Phe.	Leu.	His.
Alfalfa meal	17	59	73	40	82	71	75	77	80	74	78
Dried bakery product	10	64	85	80	84	72	81	84	86	82	86
Barley	10	78	79	81	85	77	81	82	86	87	88
Blood meal	81-89	86	91	76	87	87	87	78	89	84	88
Canola meal	38	80	90	75	90	78	82	83	87	85	87
Casein	85	97	99	84	97	98	98	98	99	96	99
Corn	8.8	81	91	85	89	84	88	88	93	94	91
Corn gluten meal	60	88	97	86	96	92	95	95	98	94	97
Corn distillers grains with solubles	27	65	84	77	63	72	81	84	89	75	88
Cottonseed meal	41	67	73	73	87	71	78	75	77	69	86
Feather meal	86	66	76	59	83	73	82	85	82	72	85
Fish meal	60-63	88	92	73	92	89	91	92	92	89	91
Meat meal	50-54	79	85	58	85	79	82	83	84	80	84
Peanut meal	46	83	88	78	84	82	88	91	92	83	94
Poultry byproduct meal	58	80	86	61	88	80	83	85	85	78	89
Rice bran	13	75	78	68	87	70	77	77	75	82	77
Sorghum	8.8	78	89	83	74	82	87	88	94	87	91
Soybean meal	48	91	92	82	92	88	91	92	92	88	93
Sunflower meal	45	84	93	78	93	85	86	90	91	87	92
Wheat	11-17	81	87	81	88	83	86	88	91	91	92
Wheat shorts	17	81	80	69	86	79	82	82	84	84	85

[1]Based on data reported by the National Research Council (1994).

For heavier broilers, it may well be advantageous to include even more diets than shown in Table 4.

While corn/soybean meal diets are regarded as ideal for poultry, there is evidence that digestibility is sub-optimal for the young chick. The idea in formulating pre-starter diets is to correct any such deficiency, and so hopefully increase early growth rate and/or improve uniformity of such early growth. Two types of pre-starter diets are used for broiler chickens. The first option is to use greater than normal levels of nutrients while the alternate approach is to use more highly digestible ingredients. Using higher nutrient density will likely compound the problem of poor digestion and so fuel gut microbial overgrowth as often seen in Europe. An alternate approach is to use more highly digestible ingredients, with little change in level of nutrients. Such pre-starter diets are very expensive, since alternative ingredients are invariably more expensive than are corn and soybean meal.

Energy values lower than those "examples" shown in Table 4 are often used commercially, and in these situations, the concentration of other nutrients must be proportionally reduced. Using lower energy diets, adjustment to energy intake is rarely 100%, and with lower-energy diets, there is often a slightly reduced energy intake. With a move to higher-energy diets, birds will often over-consume energy. This degree of adjustment applies over the range of about 2,750-3,250 kcal/kg. The diet specifications shown in Table 4 are most easily met by using corn, soybean meal, meat meal (where allowed) and supplemental fat. The limiting amino acids are methionine or methionine + cysteine. Depending upon the price of the major ingredients, synthetic methionine, lysine and threonine and perhaps tryptophan are economical. In the near future, isoleucine and valine will be available commercially.

Sodium levels shown in Table 4 are minimum requirements. Higher levels can be used, especially during hot weather conditions, as a means to stimulate water intake. The limit to diet sodium level is usually dictated by litter management.

As previously stated, the ability of the broiler to physically eat feed is the ultimate determinant of productivity. To suggest the use of low-energy diets assumes that birds can eat more of this feed. With high stocking density much past 28 days of age, birds often cannot eat enough feed to normalize energy intake, and the classical tail-off in performance — relative to standard growth curves — is often seen. This situation is complicated by any prolonged periods of darkness used in lighting programs, where birds eat less than normal amounts of feed. At high stocking density, pellet quality is often as important as feed density in sustaining growth after 28 days of age.

Broiler breeders

Diet specifications for growing breeder pullets and adult breeder hens and roosters are shown in Tables 7 and 8.

Immature pullets and roosters must be managed so as to achieve the desired uniform weight at the time of light stimulation, which is usually at around 22-23 weeks of age. Growth and uniformity are influenced by feeding program and, to a lesser extent, by feed formulation. Within reason, it is possible to achieve the desired weight at any age when using diets with a vast range of nutrient specifications, since feed allocation is controlled. For example, it is theoretically possible to grow pullets on diets with energy levels ranging from 2,600 to 3,100 kcal ME/kg. In practice, diet energy level is usually within the range of 2,750-2,950 kcal ME/kg. It is usually more difficult to maintain uniformity with high-energy diets, since this necessarily involves much smaller quantities of feed being distributed at any one time, and so feed delivery time becomes the limiting factor to uniformity.

Some type of physical feed restriction is universally used to control breeder growth. The traditional system has been skip-a-day, where, as its name implies, birds are fed only on alternate days. The skip-a-day feed intake will obviously depend upon nutrient density and environmental conditions. Controlled feeding should be adjusted to ensure that birds are cleaning up their feed on a daily basis within two hours. Feed restriction can start as early as 2 weeks or as late as 4 weeks depending on strain.

There is a trend away from skip-a-day towards everyday feeding since it is more efficient, and with superior management and supervision, better uniformity can be achieved. Improved efficiency results from birds utilizing feed directly each day, rather than there being the inherent inefficiency of skip-a-day-fed birds having to utilize stored energy for maintenance on the off-feed day. Most daily feed allowances are derived by using 50% of corresponding skip-a-day programs, but because of improved efficiency a 45% allowance is more appropriate.

Whatever system of feed restriction is used, the goals are to obtain a uniform and consistent growth rate through to

3. Vitamin and trace mineral requirements of poultry

Vitamins (per kg of diet)	Pullets/ layers	Broilers	Broiler breeders	Turkeys
Vitamin A, IU	8,000	8,000-10,000	8,000	10,000
Vitamin D3, IU	3,000	2,500-3,500	3,000	3,500-5,000
Vitamin E, IU	40-80	30-60	40-80	70-100
Vitamin K, IU	3	3	3	3
Thiamin, mg	2	2	2	3
Riboflavin, mg	5	5	10	10
Pyridoxine, mg	4	4	4	6
Pantothenic acid, mg	11	14	14	18
Folic acid, mg	1	1	1	2
Biotin, µg	80	40-100	100	250
Niacin, mg	40	40	40	60
Choline, mg	400	400	600	600
Vitamin B12, µg	10	10	10	20
Trace minerals (per kg of diet)				
Manganese, mg	60	70	80	90
Iron, mg	30	20	20	20
Copper, mg	6	8	12	12
Zinc, mg	60	80	100	100
Iodine, mg	3.0	3.0	4.0	3.0
Selenium, mg	0.3	0.3	0.3	0.3

4. Diet specifications for broilers (units per 1000 kcal ME)

Approximate age, days	Starter 0-16	Grower 17-28	Finisher 29-41	Withdrawal 42+ (or last 5 days)
(Average metabolizable energy, kcal/kg)	(3,050)	(3,100)	(3,150)	(3,200)
Crude protein, %	7.2	6.5	6.1	5.3
Calcium, %	0.31	0.29	0.28	0.26
Available phosphorus, %	0.15	0.13	0.12	0.11
Sodium, %	0.07	0.07	0.06	0.06
Dig. Methionine, %	0.15	0.13	0.11	0.10
Dig. Methionine + cysteine, %	0.28	0.25	0.23	0.24
Dig. Lysine, %	0.41	0.38	0.33	0.30
Dig. Threonine, %	0.26	0.23	0.21	0.19
Dig. Tryptophan, %	0.07	0.05	0.05	0.04
Dig. Arginine, %	0.43	0.37	0.33	0.31
Dig. Valine, %	0.25	0.19	0.16	0.14
Dig. Leucine, %	0.40	0.31	0.25	0.23
Dig. Isoleucine, %	0.22	0.19	0.15	0.13

maturity. Ideally, the pullets and roosters will be close to target weight by 18-20 weeks of age, since attempts at major manipulation in growth after this time often compromises body composition (birds get fatter) and subsequent reproductive performance.

Roosters can be grown with the hens or grown separately, but in both situations, they will almost exclusively be fed starter and grower diets designed for the female birds. This poses no major problem because nutrient requirements of the sexes up to the time of maturity are similar. When males and females are grown together, the onset of restriction programs and feed allocation are usually dictated by progress in hen weight and condition. Male growth and condition cannot be controlled as well under these situations, and this has to be an accepted consequence of mixed-sex growing systems. Growing roosters separately provides the best opportunity to dictate and control their development.

Water restriction is also important for juvenile breeders. With feed restriction, birds can consume their feed in 30 minutes to 2 hours and so given the opportunity, these birds will consume excessive quantities of water simply out of boredom or to satisfy physical hunger. Pullets given free access to water usually have wetter litter, and there is no doubt that a water restriction program is necessary in order to maintain good litter quality and help prevent buildup of intestinal parasites and maintain foot pad condition. Degree of water restriction is dictated by environmental temperature.

There is considerable variation in application and use of pre-breeder diets. While most primary breeding companies show specifications for pre-breeder diets, it is common practice to change directly from grower diet to breeder diet at around 23 weeks of age. The pre-breeder diet is really only useful as a transition diet in terms of calcium metabolism.

Adult breeders must be continued on some type of restricted feeding program. After 22 weeks of age, regardless of rearing program, all birds should be fed each day. Because energy intake is the major factor controlling egg production, then it is critical that feed intake be adjusted according to energy density of the diet. In general, most breeder flocks will be overfed protein because it is difficult to justify much more than 23-25 g of protein per day. Excess protein and amino acids contribute to muscle growth with birds becoming overweight. With a daily feed intake of 155 g, this means a protein need of only 15% of the diet. Peak feed is usually given anywhere from 30% to 60% egg production. If flocks are very uniform in weight, it is possible to peak feed at 30-40%. However, with poorer uniformity (<80% ± 15%), then peak allowance should not be given until 60% egg production or even later. Such so-called lead feeding programs are also influenced by management skills. Where there is good management with precise feed distribution, then peak feed can occur earlier.

Once birds have peaked in egg production, it is necessary to reduce feed intake. There is often confusion and concern as to how much and how quickly feed should be removed. After peak production, feed clean-up time often starts to increase, and this is an indication of birds being overfed. If feed is not withdrawn after peak, then because egg production is declining, proportionally more feed will be used for growth. With modern strains of breeder this growth can be as breast muscle and not just as fat tissue as occurred traditionally. After peak, therefore, bodyweight becomes perhaps the most-important parameter used in manipulating feed allocation. It is still important for birds to gain some weight, since loss of weight is indicative of too severe a cutback in feed allocation. The higher the peak feed allowance, the greater the amount of feed withdrawn and vice versa. For example, with a peak allowance of 175 g per day, it will be necessary to remove up to about 25 g by end of lay. With peak allowance of 155 g, only about 10 g can be withdrawn over time. Remember that the single largest factor impacting feed need is maintenance (at least 70% of intake) and that the major factors impacting maintenance are bodyweight and environmental temperature. Breeder hens can be fed a single diet through 40 weeks of production, or a diet with slightly lower nutrient density introduced midway through lay.

In breeder facilities, there is the choice of using the breeder hen diet for all birds, or a separate diet specifically formulated for males. Such male diets will usually be much lower in crude protein, amino acids and calcium compared to the breeder hen diet. The protein and amino acid needs of the mature male are very low, being in the range of 10% crude protein. Such low-protein diets are often difficult and expensive to formulate per unit of nutrients supplied, but do allow for greater control of bodyweight and consequently fertility will usually be improved. A practical compromise is to formulate diets at around 12% crude protein or to use a 14% pullet grower diet. The calcium present in the hen breeder diet is also excessively high for the male. Because it is not producing eggshells, the male needs only 0.7-0.8% calcium in the diet.

Laying hens

There has been unprecedented improvement in genetic potential of layers, such that today white-egg strains are pro-

5. Broiler male feeding schedules

	---2.2 kg---		---2.6 kg---		---3.0 kg---		---3.4 kg---		---3.8 kg---	
Feed	Days	Feed	Days	Feed	Days	Feed	Days	Feed	Days	Feed
Starter	1-18	0.75	1-18	0.75	1-18	0.75	1-18	0.75	1-18	0.75
Grower	19-30	1.45	19-31	1.60	19-31	1.60	19-31	1.60	19-31	1.60
Finisher	31-34	0.70	32-38	1.25	32-42	2.05	32-45	2.85	32-50	3.85
Withdrawal	35-39	0.85	39-43	1.00	43-47	1.15	46-50	1.15	51-55	1.15
Total kg		3.75		4.60		5.55		6.35		7.35
FC		1.70		1.77		1.85		1.87		1.93

6. Broiler female feeding schedules

	---1.75 kg---		---2.0 kg---		---2.2 kg---		---2.5 kg---	
Feed	Days	Feed	Days	Feed	Days	Feed	Days	Feed
Starter	1-17	0.70	1-17	0.70	1-17	0.70	1-17	0.70
Grower	18-30	1.40	19-30	1.35	19-30	1.35	19-30	1.35
Finisher	—	—	31-34	0.60	31-37	1.05	31-41	1.70
Withdrawal	31-35	0.80	35-39	0.80	38-42	0.80	42-46	0.80
Total kg		2.90		3.45		3.90		4.55
FC		1.66		1.73		1.77		1.82

ducing 335 eggs in 52 weeks of production. This high productivity has led to some changes in feeding practice and especially the reluctance for early reduction in diet protein and amino acids. Diet specifications for growing pullets and laying hens are shown in Tables 9 and 10, respectively. The traditional concern with early maturity has been too many small eggs. There seems little doubt that bodyweight and perhaps body composition at maturity are the major factors influencing egg size throughout the entire laying period. Bodyweight is the main factor controlling early egg size, and nutritional factors such as diet protein and methionine and linoleic acid have only limited supporting effects on egg size.

One of the most important concepts today in feeding the growing pullet is to schedule diets according to bodyweight and condition of the flock rather than ac-

7. Diet specifications for broiler breeder pullets

Age, weeks	Pre-Starter 0-4	Grower 4-12	Developer 12-22	Pre-Breeder (optional) 20-22
Crude protein, %	18.5	17	16	15.5
Metabolizable energy, kcal/kg	2,850	2,850	2,850	2,850
Calcium, %	0.95	0.92	0.89	2.20
Available phosphorus, %	0.45	0.40	0.38	0.40
Sodium, %	0.20	0.19	0.17	0.17
Dig. Methionine, %	0.38	0.32	0.29	0.30
Dig. Methionine + cysteine, %	0.72	0.65	0.52	0.55
Dig. Lysine, %	0.90	0.81	0.72	0.62
Dig. Threonine, %	0.65	0.60	0.52	0.52
Dig. Tryptophan, %	0.18	0.16	0.14	0.14
Dig. Arginine, %	1.04	0.90	0.78	0.72
Dig. Valine, %	0.68	0.63	0.59	0.54
Dig. Leucine, %	0.81	0.77	0.83	0.79
Dig. Isoleucine, %	0.63	0.54	0.46	0.43

8. Diet specifications for broiler breeders

Age, weeks	Phase 1 22-34	Phase 2 34-54	Phase 3 54-64	Male 22-64
Crude protein, %	15.5	15	14	12
Metabolizable energy, kcal/kg	2,850	2,850	2,850	2,750
Calcium, %	3.0	3.2	3.4	0.75
Available phosphorus, %	0.40	0.35	0.31	0.28
Sodium, %	0.18	0.18	0.18	0.18
Dig. Methionine, %	0.32	0.29	0.27	0.25
Dig. Methionine + cysteine, %	0.59	0.56	0.53	0.50
Dig. Lysine, %	0.72	0.67	0.61	0.59
Dig. Threonine, %	0.56	0.55	0.51	0.46
Dig. Tryptophan, %	0.16	0.14	0.13	0.12
Dig. Arginine, %	0.81	0.74	0.67	0.59
Dig. Valine, %	0.54	0.50	0.45	0.41
Dig. Leucine, %	0.72	0.67	0.63	0.58
Dig. Isoleucine, %	0.56	0.52	0.47	0.41

9. Diet specifications for growing layer pullets

Age, weeks	Starter 0-6	Grower 6-10	Developer 10-16	Pre-lay 16-18
Crude protein, %	20	18.5	16.5	16
Metabolizable energy, kcal/kg	2,900	2,850	2,850	2,850
Calcium, %	1.0	0.95	0.92	2.25
Available phosphorus, %	0.45	0.42	0.4	0.42
Sodium, %	0.18	0.18	0.17	0.17
Dig. Methionine, %	0.41	0.38	0.35	0.33
Dig. Methionine + cysteine, %	0.70	0.65	0.59	0.58
Dig. Lysine, %	0.99	0.81	0.72	0.69
Dig. Threonine, %	0.65	0.63	0.54	0.52
Dig. Tryptophan, %	0.18	0.16	0.14	0.14
Dig. Arginine, %	1.04	0.86	0.77	0.72
Dig. Valine, %	0.68	0.63	0.59	0.54
Dig. Leucine, %	1.17	0.99	0.83	0.79
Dig. Isoleucine, %	0.63	0.54	0.46	0.43

cording to either age regardless of weight, or weight in isolation of age. For example, traditional systems involve feeding starter diets for about six weeks, followed by grower and then developer diets. This approach does not take into account individual flock variation, and this will be inappropriate for underweight flocks at any age. It is becoming more difficult to achieve early weight for age, and especially in the first month of growth.

Pre-lay diets and pre-lay management are designed to allow the bird the opportunity to establish adequate medullary bone reserves that are necessary for calcifying the first few eggs that are produced. In practice, there is considerable variation in formulation and sequencing of pre-lay diets, and to some extent, this confusion relates to defining sexual maturity. Historically, pre-lay diets were fed from about two weeks prior to expected maturity up to the time of 5% egg production. With early, rapid and hopefully synchronized maturation with today's strains, we rarely have the opportunity to feed for two weeks prior to maturity. Likewise, it is unwise to feed inadequate levels of calcium when flocks are at 5% production.

Diet specifications for laying hens shown in Table 10 are categorized according to age and feed intake. There is no evidence to suggest that diet energy level has to change as the bird progress through a laying cycle, although reductions over time may help prevent obesity. The layer's peak energy needs are most likely met at around 35-40 weeks of age, when daily egg mass output is maximized. However, the layer quite precisely adjusts its intake according to needs for energy, and so variable energy needs are accommodated by change in feed intake, assuming the bird can accomplish this intake adjustment within the confines of a competitive cage environment.

Diet nutrient concentrations traditionally decrease over time, with the notable exception of the need for more calcium. Thus, diet protein and amino acids expressed as a percent of the diet or as a ratio to energy decline as the bird progresses through the laying cycle. However, this traditional approach is now being questioned in relation to the extraordinary high sustained peaks seen today, and so the phase-feeding of nutrients in consecutive diets is being tempered and/or delayed. Some strains are now capable of peaking at 98% with 40 consecutive weeks over 90% egg production. Regardless of other nutrients, it is important to increase diet calcium level and to concomitantly decrease the diet phosphorus level as the bird gets older. The need for less methionine is partially related to the need for tempering a late-cycle increase in egg size since this is usually uneconomical regarding egg pricing and the fact that larger eggs have thinner shells. However, the ability to temper egg size, while sustaining production, through use of less methionine is far from guaranteed.

With variable feed intake, it is necessary to adjust the ratios of all nutrients to energy so as to maintain constant intakes of these nutrients. While it is impractical to consider reformulation based on day-to-day fluctuations in environmental temperature, trends in feed intake associated with high versus low bodyweight, etc., should be accommodated in diet formulation. The energy level of the diet will dictate feed intake. In general, birds over consume energy with higher-energy diets, and they will have difficulty maintaining normal energy intake with diets of less than 2,700 kcal ME/kg.

The majority of the world's laying hens are kept in locations where heat stress is likely to be a major concern at some stage during the production cycle. The key to sustaining production in hot climates is to maintain a positive energy balance. This may involve the use of higher nutrient-dense diets, greater use of fat (at constant energy level) and synthetic amino acids, texturing of diets, more frequent feeding and perhaps a 1hr midnight feeding. Interestingly the first activity with midnight lighting is drinking, and so this may be as useful to the bird as is access to feed.

Eggshell quality is an ongoing issue in layer management. The important nutritional considerations are levels of calcium, phosphorous and vitamin D_3, although it should be remembered that it is difficult for a bird to deposit a strong shell around an egg with poor albumen quality. There is considerable discussion about the optimum levels of calcium to be used and the source of this calcium. Undoubtedly, layers require more calcium today since it is becoming more common to see flock average production of at least 330 eggs per year. After 40 weeks of age, at least 50% of supplemental calcium should be as large-particle limestone

10. Diet specifications for layers based on feed intake (white or brown egg)

Approximate age, weeks	-------18-32-------		-------32-45-------		-------45-60-------		-------60-70-------	
Feed intake (g/bird/day)	90	95	95	100	100	105	100	110
Crude protein, %	20	19	19	18	18	16.5	17	15.5
Metabolizable energy, kcal/kg	2,850	2,850	2,840	2,840	2,820	2,820	2,800	2,800
Calcium, %	4.4	4.2	4.5	4.3	4.5	4.3	4.6	4.4
Available phosphorus, %	0.5	0.48	0.43	0.4	0.38	0.36	0.33	0.31
Sodium, %	0.18	0.17	0.17	0.16	0.17	0.16	0.17	0.16
Linoleic acid, %	1.2	1.1	1.1	1.0	1.0	1.0	1.0	1.0
Dig. Methionine, %	0.41	0.39	0.37	0.35	0.35	0.34	0.31	0.29
Dig. Methionine + cysteine, %	0.68	0.64	0.64	0.61	0.61	0.58	0.54	0.52
Dig. Lysine, %	0.78	0.74	0.73	0.69	0.71	0.67	0.66	0.63
Dig. Threonine, %	0.63	0.60	0.58	0.55	0.54	0.52	0.50	0.47
Dig. Tryptophan, %	0.16	0.15	0.15	0.15	0.15	0.14	0.14	0.13
Dig. Arginine, %	0.80	0.76	0.74	0.71	0.70	0.66	0.67	0.64
Dig. Valine, %	0.70	0.66	0.65	0.62	0.61	0.58	0.57	0.54
Dig. Leucine, %	0.48	0.45	0.44	0.42	0.39	0.37	0.36	0.35
Dig. Isoleucine, %	0.62	0.59	0.57	0.54	0.53	0.50	0.48	0.45

11. Diet specifications for growing turkeys

	Starter	Grow 1	Grow 2	Dev 1	Dev 2	Finisher
Age (weeks)	0-4	5-8	9-11	12-13	14-16	17+
Crude protein, %	28	26	23	21	18	16
Metabolizable energy, kcal/kg	2,850	2,900	3,050	3,200	3,250	3,300
Calcium, %	1.4	1.25	1.15	1.05	0.95	0.85
Available phosphorus, %	0.75	0.7	0.65	0.6	0.55	0.48
Sodium, %	0.18	0.18	0.18	0.18	0.17	0.17
Dig. Methionine, %	0.56	0.51	0.47	0.44	0.38	0.32
Dig. Methionine + cysteine, %	0.96	0.85	0.76	0.68	0.62	0.53
Dig. Lysine, %	1.55	1.46	1.32	1.18	1.02	0.91
Dig. Threonine, %	0.82	0.79	0.75	0.69	0.62	0.56
Dig. Tryptophan, %	0.25	0.24	0.21	0.19	0.17	0.15
Dig. Arginine, %	1.59	1.50	1.41	1.27	1.09	1.00
Dig. Valine, %	1.09	1.00	0.91	0.82	0.71	0.59
Dig. Leucine, %	1.73	1.64	1.50	1.37	1.14	1.00
Dig. Isoleucine, %	1.00	0.91	0.86	0.75	0.66	0.59

or oyster shell.

Egg composition can be influenced by nutrition. Yolk color is controlled by intake of xanthophylls, and more recently, there has been interest in enriching eggs with lutein as it relates to preventing macular degeneration in humans. Birds fed 10% flaxseed produce eggs with more than 300 mg omega-3 fatty acids, while inclusion of 1% fish oil is the best way to enrich eggs with DHA.

Turkeys

Diet specifications for commercial turkeys are shown in Table 11. It is now common to grow hens to around 11-15 weeks and toms to 16-22 weeks of age. Genetic potential for growth rate of turkeys continues to increase, and standards for large tom turkeys are approaching 1 kg per week of age. Unlike most other meat birds, there are distinct differences in the market weight of males and females, so it is accepted that the sexes must be grown separately. The diet specifications shown in Table 11 are general guidelines that can be used for both male and female turkeys.

Depending upon the marketing age of hens, the diets will perhaps be scheduled a little more quickly, and/or the last diet used will be a compromise between the developer #2 and finisher as shown in Table 11.

The turkey will grow quite well using diets with a range of nutrient densities, although grow-out time will increase and classical feed efficiency will decrease, when lower nutrient-dense diets are used. Poorer performance than expected with some high-energy diets is often a consequence of not adjusting amino acid levels to account for reduced feed intake. Another factor is the ability to sustain good pellet quality with higher energy diets. There is an indication that modern strains of turkey are now more responsive to protein and amino acids at older ages. It is sometimes quite challenging to sustain pellet quality in high fat/energy finisher diets.

There are a number of health issues that influence early poult development and, perhaps, the formulation of starter diets. Poult enteritis and mortality syndrome (PEMS) has been a serious problem in isolated regions of the world. The condition is likely caused or accentuated by the presence of viruses, and poults can be artificially infected by dosing with intestinal contents from other infected birds. While high mortality is sometimes experienced, there is a secondary problem of stunting, where affected birds do not show compensatory growth. Recent data suggest that turkeys that recover from PEMS have impaired digestion/absorption of most nutrients.

So-called field rickets continue to be an ongoing problem at certain farms. Since some farms seem to have greater occurrence than others, there has always been suspicion of an infectious agent. However, when homogenates from the digesta of affected poults are fed to normal birds, there is no effect on poult livability or skeletal developments. Obviously, dietary levels of calcium, phosphorus and vitamin D3 come under close scrutiny, but rickets does not seem to be a simple deficiency of any one of these nutrients.

With the high levels of lysine needed in prestarter/starter diets, there is often concern about the need for arginine. The usual recommendation is to have arginine at 110% of lysine, so when digestible lysine is at 1.65%, arginine needs are close to 1.80% of the diet. This level of arginine may be difficult to achieve, and under these situations, arginine at 102% of lysine is more economical. The current use of highly digestible pre-starter diets for broilers seems to be an obvious application in poult nutrition.

In diets composed essentially of corn and soybean meal, methionine and/or total sulfur amino acids are likely to be the limiting amino acids. Requirement for methionine will obviously vary with energy level of the diet, although it is possible to make general recommendations of around 2.2, 1.9 and 1.6 mg digestible methionine per kcal ME for starter, grower/developer and finisher diets, respectively. Digestible lysine levels are, therefore, around 5.9, 5.1 and 3.6 mg/kcal ME for starter, grower and finisher diets, respectively. Most nutritionists consider the turkey to be very responsive to lysine levels, although as a percentage of crude protein, the levels used in practice are little different than for other meat birds.

Utilization of fats in diets for turkeys has always been a controversial topic and certainly one that has received considerable attention over the years. In many instances, research protocols fail to differentiate between the effects of fat and energy. Considering the role that energy plays in controlling growth, it is perhaps not too surprising that turkeys respond to supplemental dietary fat. At fixed energy levels, there is often improvement in feed efficiency with added fat, and this effect increases with increased bird age. From 0 to 20 weeks, feed efficiency is improved about 1.5% for each 1% added fat. From 12 to 20 weeks, a corresponding value of 3.5% is seen. It is often noted that if fat is removed from the diet of older birds, then any improvements to that time are often lost. These data suggest little return in use of fat for young birds, and that economic response is maximized after eight weeks of age. The age response is likely a reflection of digestibility of more saturated fatty acids coupled with the improved efficiency associated with direct deposition of absorbed fats into body fat depots. The young turkey is an exceptionally lean bird, and so there is little fat synthesis or deposition before 8-10 weeks of age. The turkey's response to energy is to some extent influenced by environmental temperature. The optimum temperature for growth rate is much less than that for optimum feed efficiency and for large tom turkeys after 12-14 weeks may well be close to just 10-12°C. ■

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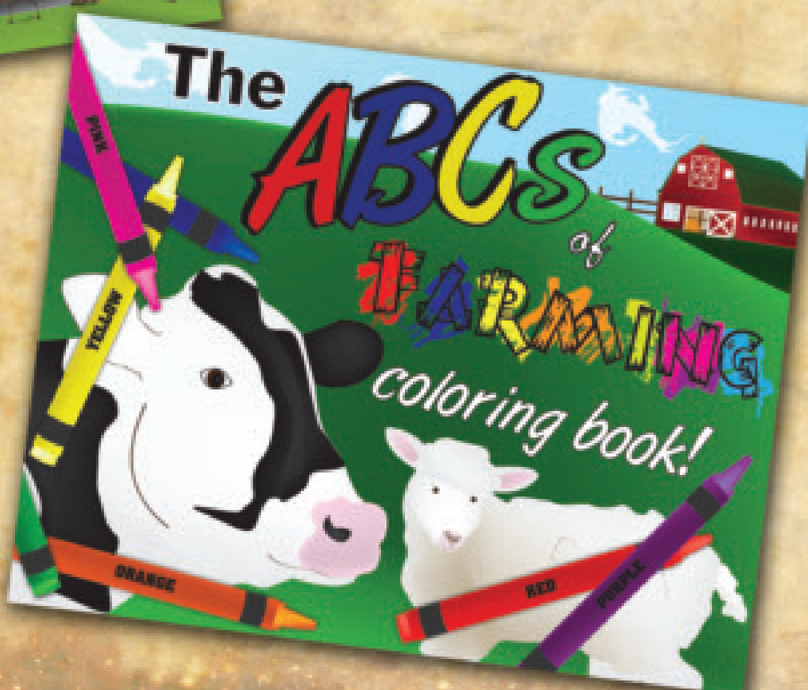

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