

PROTEIN AND ENERGY REQUIREMENTS OF LAYING HENS AND BROILER BREEDERS

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CALCULATING AMINO ACID REQUIREMENTS

Layer and Breeder rations are still evaluated, as a rule, on the basis of their protein content, expressed as "percent protein". This is the easiest and most practical criterion, but unfortunately it is a relative measure, depending on general feed consumption. The latter hardly relates to the productive traits of the hen, being dependent primarily on the energy content of the feed and on the environmental temperature, with body weight of the birds coming only in third place, and with performance having even less of an effect,

Expressing the requirements of laying hens as grams protein per hen per day is a great improvement over "% protein", but this measure does not take into account two groups of factors which should determine, even on a purely intuitive basis, the quantity of protein needed by the layer, namely: performance characters (rate of production and egg size) and the amino acid pattern of the dietary protein. The more the latter resembles that of the egg protein, the less feed protein is required.

Since recommendations for dietary protein levels must take into consideration its amino acid make-up, a number of research workers have studied the requirements of laying hens for various amino acids, Unfortunately several of them have reverted to the above mistake of expressing these requirements as % of the diet, However, even in terms of mg/hen/day, and for all 10-12 essential amino acids, there remain decided variations among the recommendations of different authorities, due to differences in laying performance and body weight, besides the influence of variations in experimental techniques,

Some poultry nutritionists (Fisher 1958; Scott et al 1960; Combs 1961) came to the conclusion, therefore, that there could not exist a single set of requirements which would fit all conditions. As an alternative they proposed to express the biological requirements by mathematical partition equations. The latter were based on requirements for three functions: body maintenance, body weight gain and egg production. However, the algebraic sum of these three types of requirements always resulted in a decided underestimate of the requirements as determined empirically. This difference between actual and calculated requirements was attributed to the relative inefficiency of the hen in converting feed protein to egg protein (Scott 1961).

Moran and Chiah (1971) expressed, rather incidentally, a thought which has bothered us for a long time, without drawing the necessary conclusion, namely, that the egg albumen was secreted by the oviduct in such a short time, that this amount of protein could not possibly come directly from the digestive tract and/or the muscosal lining of the oviduct, Whereas the formation of egg yolk is a continuous process, egg white formation (including shell membranes) is a short spurt-like process of approximately 4 hours, during which almost 4 g protein are secreted, Considering a 85% absorption of nitrogenous

TABLE 1. Selected amino acid composition of various proteins and its requirement for body maintenance (Hurwitz and Bornstein 1973)

Amino acid	Maintenance	Tissue	Yolk	Albumen	Ovo-mucoid	Ovalbumen	Shell membr.
		(% of N x 6.25)					
Methionine	4.1	1.8	2.8	4.2	4.8	1.7	?
C. + M.*	5.1	3.6	4.8	7.2	6.7	7.9	12.7
Lysine	1.7	7.5	5.5	7.2	6.4	7.3	5.2
Arginine	6.8	6.7	7.3	6.0	6.0	5.4	12.9
Threonine	4.2	4.0	5.3	5.0	4.2	6.7	?
Valine	3.5**	6.7	7.3	7.5	8.5	7.3	?
Isoleucine	4.1	4.1	6.8	6.5	7.0	1.7	?
Leucine	7.1	6.6	8.5	8.8	9.0	6.1	7.4
Tryptophane	1.1	0.8	1.5	1.2	1.4	2.2	2.2
Histidine	0	2.0	1.8	2.4	2.3	2.6	4.2
Ph. + Ty.*	3.4	6.4	9.7	9.2	11.1	9.2	3.3

* Sulphur amino acids and combined phenylalanine and tyrosine, respectively.

** Corrected to 2.8% on the basis of later research (Hurwitz and Bornstein, unpublished data).

compounds (Lepkovsky *et al.* 1965; Hurwitz *et al.* 1972) and relatively low feed consumption during albumen secretion (Mongin 1971), synthesis and secretion of almost 1 g protein per hour directly from dietary amino acids appears rather improbable.

As a consequence of the above considerations, we assumed that part (or even most) of the amino acids needed for egg white and shell membrane formation was derived from the breakdown of tissue protein, which together with intestinal absorption supplies the free amino acid pool, represented by the plasma pool (Salter *et al.* 1971). The importance of storage protein in egg formation has been pointed out by Harms *et al.* (1971).

Compared to tissue protein, albumen contains six amino acids in slightly higher concentrations, and about twice as much sulphur amino acids (Table 1). This difference in the respective composition of storage site and target thus determines the efficiency of utilization of the former? two units of tissue protein being needed for the formation of one unit of albumen protein. Hence it appears, that the movement of amino acids in the body, rather than the overall processes of "utilization", may account for the inefficiency of the conversion of feed protein to egg protein.

DEVELOPMENT OF MODELS

In the original paper (Hurwitz and Bornstein 1973) two models were used, both based on partitioning the egg proteins according to the

following proportional groupings:

Egg yolk proteins	44%
Ovalbumins	42%
Ovoglycoproteins	10%
Shell membrane proteins	4%

In both models the hen is considered to be in a "steady state" with regard to body maintenance, body weight gain and yolk formation. The models differ with respect to the need for tissue breakdown in the synthesis of egg white proteins, the assumption being in both cases that the amino acid composition of the protein(s) broken down in this process is represented by that of the tissues of the chicken as detailed in Table 1.

In Model A the assumption was made that all amino acids needed for albumen and shell membrane formation are derived from the breakdown of tissue protein, whereas Model B is based on the premise, as detailed in the original paper (Hurwitz and Bornstein 1973), that the ovalbumins of the egg white are also continuously synthesised (and stored in the magnum), and only the synthesis of ovoglycoproteins and shell membrane proteins involves the inclusion of tissue-derived amino acids. Due to their high cystine content, shell membrane proteins contain an almost four-fold concentration of sulphur amino acids than does tissue protein (Table 1), thus seriously affecting the efficiency of this conversion.

The actual calculations are performed in two stages: (a) the determination of the amino acid requirements in terms of mg/hen/day, and (b) using the latter as part of a least-cost linear computer program, allowing "protein" to run free, Table 2 presents a set of simplified formulae for 11 essential amino acids (or their combinations). These formulae require knowledge or estimates of anticipated egg mass (% production x g egg weight), body weight and body weight gain, as well as daily feed consumption per hen for computer programming. The rations obtained on the basis of these two models were reasonable and practical, and moreover resulted in a marked saving in protein under Israeli feed ingredient conditions,

PRACTICAL APPLICATION OF THE MODELS

So far seven experiments have been conducted with egg-type layers: Leghorn and crossbreds, in cages and on litter, during peak of lay and (once) toward the end of the laying year. Comparisons between Models A and B showed, that Model A overestimated the requirements while Model B-based diets produced an egg mass restricted to the target, thus being a good approximation of the true amino acid requirements, at least with regard to the most limiting ones.

As an example of the type of trials performed, the results of the first experiment of this series are summarized in Tables 3 and 4. Rate of production was significantly lower in birds receiving the Model B diet than in those fed the Model A diet or in the control birds, In terms of egg mass, egg production of Model A hens exceeded the target function, whereas Model B birds produced exactly as planned. The feed intake of the latter was slightly higher than anticipated, but their body weight slightly exceeded that predicted. The experimental diets were purposely formulated for performance lower than the genetic

TABLE 2. Simplified formulae for calculating the daily requirement of laying hens for the different essential amino acids, expressed as mg/hen/day*

Amino acid	W ^{**}	G ^{**}	EM ^{**}
Methionine ^{***}	76.21	3.81	5.50
C. + M. ^{****}	94.80	7.62	8.80
Lysine	31.60	15.88	11.09
Arginine	126.40	14.19	11.55
Threonine	78.07	8.47	7.84
Valine	52.10	14.19	13.03
Isoleucine	76.21	8.68	10.48
Leucine	131.98	13.98	14.01
Tryptophane	20.45	1.69	2.17
Histidine	0.19	4.23	3.51
Ph. + Ty. ^{****}	63.20	13.55	15.89

* Recalculated by M.R.Patchell (Poultry Research Centre, Massey University, New Zealand) from the original general equation for Model B (Hurwitz and Bornstein 1973).

** W, G and EM are the body weight(kg), weight gain (g/day) and egg mass (g/hen/day), respectively.

*** The formula for calculation: $76.21 W + 3.81 + 5.50 EM$.

**** Combined cystine + methionine and phenylalanine + tyrosine, respectively.

capacity of the birds, in order to better test the models, and the decisive point is the resemblance between target and actual performance data,

The models were also tested in four broiler breeder experiments, with equal success. Table 5 briefly summarises one such trial. The hens were fed ad lib., in order to prevent the introduction of confounding factors. During a 10-week period of peak production (74% of 66 g eggs, i.e. an egg mass of 49 g/day) the Model B birds consumed per day only 21.9 g protein containing merely 870 mg lysine but 890 mg sulphur amino acids.

The very fact that one set of equations is flexible enough to fit such different conditions as represented by the light Leghorn hen and the heavy broiler-type White Rock hen, and their varied types of production performance, seems to indicate that the principles behind the calculations are sound.

ENERGY REQUIREMENTS

Once amino acid requirements can be calculated in terms of daily intake, feed restriction of laying hens (egg layers or broiler breeders) can finally be put on a sensible basis. Feed restriction

TABLE 3. Composition of diets used in trial 1 (%)

Diet	Control	Model A	Model B
<u>Ingredients</u>			
Fish meal	2.0		
Soybean m. (45% prot.)	17.50	15.60	9.30
DL-methionine	0.06	0.12	0.17
Feather meal (hydrol.)			1.00
Soybean hulls		1.10	1.70
Yellow maize	10.00	7.80	18.10
Sorghum (milo)	60.19	63.83	58.08
Limestone	7.30	8.40	8.40
Dicalcium phosphate	1.40	1.60	1.70
Constant ingredients*	1.55	1.55	1.55
<u>Composition</u> (calculated)			
Metab. energy (kcal/kg)	2817	2750	2750
Cr. protein	15.40	13.60	11.90
Methionine	0.29	0.30	0.33
C. + M.	0.51	0.50	0.52
Lysine	0.78	0.63	0.48
Arginine	0.93	0.83	0.67
Threonine	0.57	0.52	0.44
Valine	0.75	0.68	0.61
Leucine	1.57	1.42	1.30
Isoleucine	0.69	0.63	0.53
Tryptophane	0.21	0.18	0.15
Histidine	0.36	0.33	0.28
Phenylalanine	0.80	0.74	0.62
Ph. + Ty.	1.37	1.27	1.08

* Percentage of diet: soybean-oil soapstock, 1.00; sodium chloride, 0.30; vitamin and trace mineral mix, 0.25.

which limits the consumption of all nutrients for the laying bird, cannot possibly be the aspired goal. The latter should be the feeding to requirement of all nutrients, plus certain margins of safety, rather than the quantitative restriction of a diet containing certain excesses to begin with. Since under ad lib, conditions all layers, and especially broiler breeders, tend to consume more energy than required, feed restriction is a means to obtain energy restriction, as long as it can be safeguarded that the former does not cause a suboptimal intake of any other essential nutrients. In other words, the more severe the feed restriction, the higher the required concentration of all nutrients

TABLE 4. Performance* of crossbred hens fed diets formulated according to two models for calculating amino acid requirements (trial 1)**

Parameter	Control	Model A	Model B
Rate of production	81.6a***	79.0a	76.6b
Egg weight (g), initial	58.4	59.2	59.4
final	60.9b	62.7a	61.7b
Egg mass (g/day)****	48.7	47.8	46.2
Body weight (g), initial	2167	2159	2170
final	2291	2234	2214
Feed intake (g/day)	120a	117b	122a
Feed conversion (g/egg)	147a	149a	160b

* The calculated amino acid requirements were based on the following targets: egg mass, 46 g/day; body weight, 2130 g; weight gain, 1.0 g/day. Daily energy intake was estimated at 330 kcal, or 120 g of a diet containing 2750 kcal/kg.

** Averages of six replicates of 12 layers each, during a 3-months period (Jan.-March, 1973).

*** Means not followed by a common letter differ significantly ($P < 0.05$).

**** Calculated from lot averages.

(with emphasis on the amino acids) except for energy.

Minimum energy requirements can be determined experimentally or calculated on the basis of partition equations. The literature on the latter approach has been adequately reviewed in recent publications (Leeson *et al.* 1973; Gleaves *et al.* 1973; Ivy and Gleaves 1973). Good examples of the empirical approach with egg layers and broiler breeders are the papers of Auckland and Fulton (1973) and Chaney and Fuller (1975), respectively,

Two experiments have been performed with broiler breeders, during 15-week periods of peak performance, in windowed litter pens during Israeli winter conditions of two consecutive years. The temperatures ranged from an average minimum of about 10°C at night to an average maximum of around 20°C during daytime. Each trial consisted of 3 or 4 graded degrees of feed restriction, and one lot of hens fed *ad lib.* (4 pens of 42 White Rock layers each per treatment), all birds having a uniform daily intake of amino acids. On the basis of both of these experiments it is suggested, that White Rock hens weighing approximately 3.5 kg and laying 65-g eggs at rates of 75% and 73%, can be restricted to 4.52 and 448 kcal (ME)/hen/day, respectively, with only a slight decrease in egg size (1.0 and 2.0 g, respectively). The latter is an advantage rather than a disadvantage with broiler breeders after more than 3 months production (when many eggs tend to become too large for efficient use as hatching eggs). These restrictions constituted approximately 86% and 79%, respectively, of the daily energy intake of control hens fed *ad lib.*

TABLE 5. The performance of White Rock broiler breeders during a 15-week period*

Diet**	Control	Model A	Model B
Protein level (%)***	16.1	12.1	11.0
Sulphur amino acids (%)	0.49	0.42	0.45
Lysine (%)	0.76	0.53	0.44
Rate of production (%)	71.1	73.0	71.6
Egg weight (g), average	67.7	66.4	66.7
final	69.5	68.5	69.1
54 -73 g (%)****	85	89	88
Egg mass (g/hen/day)	48.1	48.5	47.8
Body weight, initial (kg)	3.236	3.254	3.262
weight gain (g)	853	899	894
weight gain (g/day)	8.0	8.4	8.4
Feed intake (g/hen/day)	193	200	200
Feed conversion (g/egg)	274	276	283
Mortality (%)	1.8	1.2	0.6

* Averages of 4 pens, 42 hens in each.

** The diets were fed ad lib. They contained 2650 kcal/kg.

*** These calculated values were about 0.5 percentage units lower than the assayed values.

**** % eggs in this weight range out of the total number of eggs produced.

Chaney and Fuller (1975) reported that a 20% reduction in energy intake decreased rate of production and egg size significantly during the cold winter months, but had no effect on performance during the summer months. Combs (1968) suggested the following equation to calculate daily energy needs of egg layers, expressed as ME kcal/hen:

$$ME = 1.45 W^{0.75} \times (1.78 - 0.012T) + 3.13 G + 3.15 EM$$

where T is temperature (in degrees F), W = body weight (in g), G = daily body weight change (in g), and EM = egg mass (in g/hen/day). When this formula is applied to the above data (for an ambient temperature of 60°F), the calculated requirement amounts to about 465 kcal/hen/day. The empirical and calculated results are thus in good agreement, and appear to indicate that careful energy restriction in broiler breeders may be a convenient means to reduce excessive egg size.

SUMMARY

The evolution of a method for calculating the amino acid requirements of egg layers and broiler breeders (in terms of mg/hen/day) has been described, and a set of simplified formulae for 11 essential

amino acids has been presented.

The latter appear to be a good approximation of the true requirements, if to judge by seven trials with egg layers in which Model B-based diets produced an egg mass closely resembling the planned target performance. The above models were also tested in four broiler breeder experiments with equal success.

Knowledge of the amino acid requirements of laying hens, on a mg/hen/day basis, should enable the use of energy restriction (by means of feed restriction) without causing a suboptimal amino acid intake.

Broiler breeder hens averaging 3.5 kg body weight, and housed in pens with a natural temperature cycle ranging, on the average, from 10°C to 20°C, were able to produce at a 10-week average rate of 74% eggs weighing 65 g, when restricted to 450 kcal/hen/day of metabolizable energy. The latter represent about 83% of the daily energy intake of hens fed ad lib.

On the basis of these data it appears possible to "tailor" diets to all given circumstances,

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