ESTIMATION OF THE TRYPTOPHAN REQUIREMENT OF CHICKENS FOR MAXIMUM BODY WEIGHT GAIN AND FEED EFFICIENCY

A. ROSA[1] and G. M. PESTI
Department of Poultry Science, The University of Georgia,
Athens, Georgia 30602-2772
Phone: (706)542-1351
FAX: (706)542-1827

Primary Audience: Nutritionists, Researchers

SUMMARY

Tryptopahn is an essential amino acid for chickens and has many metabolic roles. The world's literature on the tryptophan requirement of starting chickens (0 to 3 weeks) was reviewed. Data were pooled from 29 different experiments into two groups: broilers and other genotypes. The nonlinear mathematical models [ascending line with plateau (ALP) and ascending quadratic line with plateau (AQP)] were fitted to estimate the tryptophan requirement from these data sets. The tryptophan requirements estimated for body weight gain (BWG) and feed efficiency (FE) of broilers using the ALP model were 0.20 ± 0.002% (BWG) and 0.25 ± 0.2% (FE). Using the AQP model, the requirements were 0.24 ± 0.004% (BWG) and 0.29 ± 0.03% (FE). The tryptophan requirements for the other stocks using the ALP model were 0.24 ± 0.02% (BWG) and 0.20 ± 0.02% (FE). Using the AQP model, the requirements were 0.32 ± 0.06% (BWG) and 0.28 ± 0.05% (FE). Based on this analysis, it was concluded that the current National Research Council (NRC) [1] estimate of the tryptophan requirement (0.20% of the diet) is probably low.

Key words: Tryptophan, broilers, chickens

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DESCRIPTION OF PROBLEM

Tryptophan is an essential amino acid for chickens that is necessary for maximum growth and FE; its levels influence behavior and carcass composition. Recently, it was found that tryptophan has a sedative effect because of its influence on levels of the neurotransmitter serotonin [2, 3]. Several studies [4, 5, 6] have indicated that an increase in tryptophan levels causes a decrease in the total liver lipids of broilers and layers. Reports on the tryptophan requirements for chicks up to 21 days of age have varied widely. Levels as low as 0.13% to 0.16% of the diet to as high as 0.25% of the diet have been suggested for the tryptophan requirements of broilers [5, 7, 8, 9, 10, 11]. The NRC [1] reduced the previous tryptophan requirement recommendation [12] from 0.23 to 0.20% for broilers from 0 to 3 weeks of age. Most research estimates of tryptophan requirements have been based on multiple range test

[1] Present address: Department of Animal Science, Federal University of Santa Maria, RS Brazil, CAPES Foundation, Brazil. To whom correspondence should be addressed.

TABLE 1. Summary of the data of male broiler chickens evaluated

DIETARY TRYPTOPHAN RANGE (%)	MAXIMUM BWG	MAXIMUM BWG/FEED	AGE DURING TRIAL	STRAIN	REFERENCE	YEAR
	(g/day)	(g/g)	(days)			
0.170–0.250	19.30	0.530	7 to 21	—	8	1972
0.140–0.250	20.50	0.610	7 to 21	—	14	1972
0.110–0.304	16.70	0.552	7 to 14	Cobb	15	1979
0.110–0.304	26.20	0.556	14 to 21	Cobb	15	1979
0.160–0.285	25.86	0.675	7 to 20	Vantress × Arbor Acres	11	1988
0.120–0.216	16.20	0.548	4 to 8	Ross	16	1990
0.135–0.243	18.40	0.584	4 to 8	Ross	16	1990
0.150–0.270	18.90	0.598	4 to 8	Ross	16	1990
0.165–0.297	19.00	0.635	4 to 8	Ross	16	1990
0.180–0.324	20.30	0.633	4 to 8	Ross	16	1990
0.195–0.531	20.20	0.654	4 to 8	Ross	16	1990
0.210–0.378	20.40	0.661	4 to 8	Ross	16	1990
0.225–0.405	20.00	0.654	4 to 8	Ross	16	1990

[A]BWG = body weight gain.

analyses without any indication of the confidence in the resulting estimates. Non-linear regression fitting techniques have an advantage over multiple range test approaches [13] because they can be used to evaluate data and estimate the requirement and its confidence interval. In view of conflicting reports on tryptophan requirements and large variations in requirement estimates among experiments, we evaluated this amino acid. Our goal was to pool data [8, 9, 10, 14, 15, 16, 17, 18, 19, 20] for non-linear regression fitting to achieve the best estimate of the starting chicken's requirement.

Materials and Methods

We arbitrarily decided to include only data from males for the broiler chickens group (Table 1), but both sexes were included in the other stocks group (Table 2). Most of the data for broilers came from experiments with males only; more data for other genotypes came from experiments with female chicks. Some experiments with broilers were eliminated because they used males and females [21]. Data were not included from experiments using purified diets [22] or from experiments with a trial length of more than 3 weeks.

The non-linear regression procedure of SAS [23] was used to fit the response data because it gives acceptable results and does not take excessive time with modern microcomputers. This iterative procedure yields repeated summations for the coefficients until the best-fit line is achieved. Based on the shapes of the observed response curves, the ALP and AQP models were used. These models were chosen because they fit the data well and provided estimates of requirements per se unlike other non-linear models that exhibit a smooth transition from ascending to plateau portions of the response curves.

The ALP can be represented as

$$Y = MAX + RC * (REQ - X) * I, \text{ and}$$

the AQP can be represented as

$$Y = MAX + RC * (REQ - X) ** 2*1$$

where X = independent variable, REQ = requirement, Y = dependent variable, I = 0 (or 1 if X < REQ), MAX = theoretical maximum, and RC = rate constant. The R^2 were determined as follows: $R^2 = 1 - $ (residual sum of squares/ corrected total sum of squares).

Results and Discussion

The maximum responses for BWG of broiler chickens were approximately double those of the other genotypes, although the maxi-

TABLE 2. Summary of the data of the other stocks (non-broiler) evaluated

DIETARY TRYPTOPHAN RANGE (%)	MAXIMUM BWG[A]	MAXIMUM BWG/FEED	AGE DURING TRIAL	SEX	STRAIN[B]	REFERENCE	YEAR
	(g/day)	(g/g)	(days)				
0.070–0.210	6.60	0.270	10 to 20	M	1	17	1956
0.060–0.110	6.20	0.270	10 to 20	M	1	17	1956
0.130–0.330	11.70	0.480	10 to 20	M	1	17	1956
0.110–0.210	11.20	0.490	10 to 20	M	1	17	1956
0.130–0.370	10.00	0.480	10 to 20	M	1	17	1956
0.110–0.210	10.60	0.520	10 to 20	M	1	17	1956
0.130–0.400	9.10	0.480	10 to 20	M	1	17	1956
0.130–0.210	8.00	0.460	10 to 20	M	1	17	1956
0.075–0.225	8.00	—	7 to 14	M	1	18	1960
0.150–0.300	15.00	0.820	8 to 14	M	2	19	1965
0.036–0.126	6.65	0.460	8 to 14	F	1	07	1971
0.048–0.168	8.40	0.550	8 to 14	F	1	07	1971
0.060–0.210	10.27	0.650	8 to 14	F	1	07	1971
0.072–0.252	11.42	0.730	8 to 14	F	1	07	1971
0.084–0.294	12.18	0.890	8 to 14	F	1	07	1971
0.160–0.192	3.56	—	7 to 17	M/F	3	20	1972

[A]BWG = body weight gain.
[B]Strain: 1 = New Hampshire × Columbian, 2 = New Hampshire or Peterson × Columbian, and 3 = White Leghorn.

TABLE 3. Coefficients estimated for the body weight gain (BWG) and feed efficiency (FE) responses of broiler chickens to dietary tryptophan level (from the data in Table 1 and Figures 1 and 2)

	BWG		FE	
PARAMETER	ALP[A]	AQP[B]	ALP	AQP
Tryptophan requirement	0.20 ± 0.002	0.24 ± 0.004	0.25 ± 0.014	0.29 ± 0.027
Maximum response	20.19	20.44	0.62	0.62
Rate constant	−66.59	−303.20	−1.15	−5.78
R^2	0.24	0.25	0.52	0.56
Observations, no.	72	72	72	72

[A]ALP = nonlinear mathematical model ascending line with plateau.
[B]AGP = nonlinear mathematical model ascending quadratic line with plateau.

TABLE 4. Coefficients estimated for the body weight gain (BWG) and feed efficiency (FE) of responses of other chickens (non-broilers) to dietary tryptophan level (from the data in Table 2 and Figures 3 and 4)

	BWG		FE	
PARAMETER	ALP[A]	AQP[B]	ALP	AQP
Tryptophan requirement	0.24 ± 0.021	0.32 ± 0.054	0.20 ± 0.020	0.28 ± 0.052
Maximum response	11.06	10.99	0.59	0.60
Rate constant	−42.83	−121.94	−2.40	−7.73
R^2	0.50	0.49	0.41	0.41
Observations, no.	95	95	83	83

[A]ALP = nonlinear mathematical model ascending line with plateau.
[B]AGP = nonlinear mathematical model ascending quadratic line with plateau.

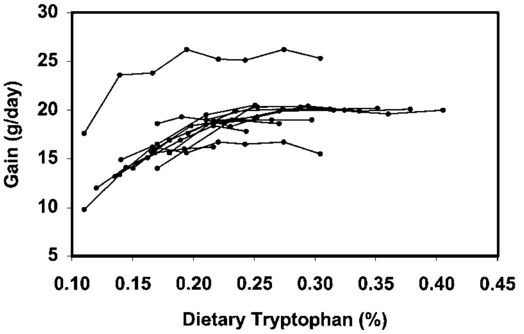

FIGURE 1. Body weight gain data used to estimate the tryptophan requirements of broiler chickens.

mum responses for FE were very similar (Tables 3 and 4). The tryptophan requirements for BWG were lower for the broiler strains than for the other chickens using either the ALP (0.20 vs. 0.24%) or AQP (0.24 vs. 0.28%) models. Tryptophan requirements for FE were higher for the broiler strains using the ALP model (0.25 vs. 0.20%) and quite similar using the AQP model (0.29 vs. 0.28%).

As expected, the amount of dietary tryptophan needed to maximize performance was greater for FE than for BWG and was greater for the AQP model than for the ALP model. Similar results were obtained in a study of lysine requirements [13]. The tryptophan requirement for broilers, as estimated for daily BWG using the ALP model, was similar to the current NRC recommendation [12]; however, estimates based on FE and the AQP model were higher.

Morris [24] stated that the ALP model always permits a false deduction about the optimum input. Several researchers have concluded

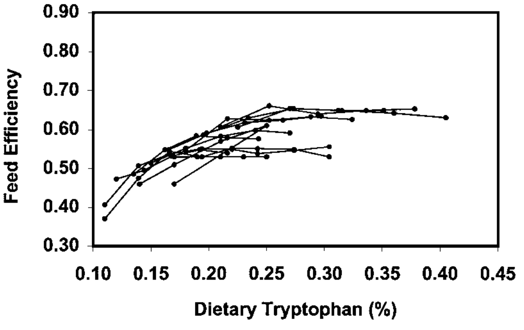

FIGURE 2. Feed efficiency data (g gain/g intake) used to estimate the requirements of broiler chickens.

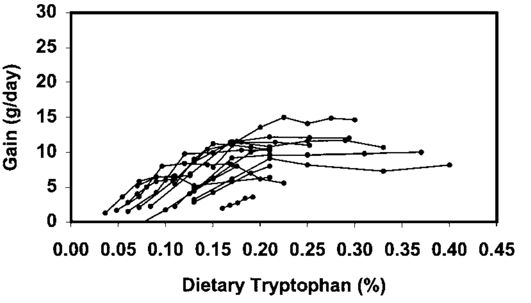

FIGURE 3. Body weight gain data used to estimate the tryptophan requirements of other chickens (non-broiler).

that nutrient requirement models based on diminishing returns-type functions should describe nutrient responses better than the ALP model [24, 25, 26]; thus, the higher requirement may be theoretically justified.

The ALP model had a higher R^2 than the AQP model for daily BWG for other stocks (0.50 vs. 0.24). The ALP and AQP models had the same R^2 for FE for other stocks (0.41), but the requirements estimated were very different.

The large difference in tryptophan requirements between broiler chickens and other stocks may not be surprising because of genetic differences between the birds and the time periods involved (before and after 1972). Comparing Figures 1 and 2, one can observe the enormous differences between bird responses.

The variety in requirement estimates may be due to differences in the genetics of the birds as related to growth rate, basal diets, amount of protein in the diets [16], and other unidentified factors. The unidentified factors could include

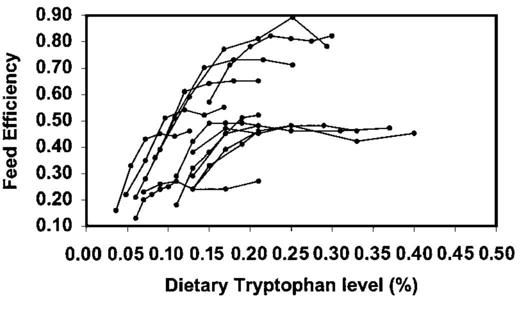

FIGURE 4. Feed efficiency data (g gain/g intake) used to estimate the requirements of other chickens (non-broiler).

amino acid imbalances. Adequate niacin levels in each study should eliminate any interaction with niacin as a causative factor.

A likely cause of some variation in the tryptophan requirement estimates is the difficulty in determining the amount of tryptophan in basal diets. Several different analytical techniques were used in the research reports in Tables 1 and 2 [27, 28, 29, 30] and in no case was any estimate of accuracy in the analytical techniques presented.

The model fitting procedures used here are interesting techniques to estimate amino acid requirements as well as the requirements of other nutrients. Practicing nutritionists need to consider that broken-line models will yield higher requirement estimates than multiple range test approaches, and AQL models will yield even higher estimates. Decisions between models are difficult because the R^2 between ALP and AQP models are very similar; however, the requirement estimates are not. The use of the AQP model estimate of 0.25% tryptophan may be the most prudent. It should include a reasonable margin of safety to maximize performance and minimize liver lipids [3, 4].

Conclusions and Applications

1. Values for tryptophan requirements from 29 experiments in the literature vary from 0.14 to 0.24% of the diet. The experiments can be logically divided into two groups: experiments after 1972 using male broiler chickens, and experiments before 1972 using several slower growing stocks.
2. Tryptophan requirements estimated by an AQP model, based on daily BWG and FE, were higher than the estimations made by the ALP model.
3. Based on this analysis, the current NRC [1] tryptophan requirement estimate of 0.20% is probably too low for broilers. These analyses suggest that at least 0.25% tryptophan is necessary to maximize FE.

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