Lysine, methionine, phenylalanine, arginine, valine, isoleucine, leucine, and threonine maintenance requirements of broiler breeders

N. K. Sakomura,[1] R.D. Ekmay,[2] S. J. Mei,[3] and C. N. Coon[4]

University of Arkansas, Center of Excellence for Poultry Science, Fayetteville, AR 72701

ABSTRACT Five hundred and sixty Cobb-Vantress broiler breeders were used to determine the maintenance requirement of dietary Arg, His, Ile, Leu, Lys, Met, Phe, Thr, and Val in 10 21-d assays using the comparative slaughter technique. Fifty sexually immature broiler breeder pullets per assay were given crystalline amino acid diets containing graded levels of Arg, His, Ile, Leu, Lys, Met, Phe, Thr, or Val, respectively, representing 0, 10, 20, 30, 40% of their suggested requirement level (NRC, 1994) with all other amino acids maintained at 40% of their suggested requirement level. Sixty hens were slaughtered prior to the beginning of the study to assess initial body composition at 3 weight groups. Linear regression lines (protein accretion vs. amino acid intake) were determined and the maintenance requirements were calculated based on zero protein accretion. The maintenance requirements expressed on a metabolic weight basis were determined to be 174, 94, 52, 81, 60, 126, 133, and 155 mg/kg$^{0.75}$/d for Arg, Ile, Leu, Lys, Met, Phe, Thr, and Val, respectively. Additionally, the maintenance requirements, expressed on metabolic protein weight basis, were determined to be 651, 329, 172, 295, 223, 523, 478, and 546 mg/kgCP/d for Arg, Ile, Leu, Lys, Met, Phe, Thr, and Val, respectively. The requirement for His could not be established as the results obtained were outside of assay range.

Key words: broiler breeders, maintenance, requirements, amino acids

2015 Poultry Science 94:2715–2721
http://dx.doi.org/10.3382/ps/pev287

INTRODUCTION

The total amino acid requirement of a growing bird includes 2 components, a requirement for maintenance and a requirement for tissue protein accretion. There is evidence that the pattern of amino acids required for each of these 2 components is quite different, and the bird's total requirement must depend on the relative contributions of maintenance and tissue protein accretion to its total need (Fuller et al., 1989). Obligatory amino acid losses account for a portion of the maintenance requirements. These may arise through increased losses in the digestive tract, increased oxidation, or by other routes; collectively, these increased losses result in reduced efficiency of amino acid utilization (Fuller, 1994).

There have been a variety of methodologies utilized for the determination of maintenance requirements in broiler breeders (Gous et al., 1984, Nonis and Gous, 2008, Bonato et al., 2011). The maintenance amino acid requirement is normally defined as nitrogen equilibrium, the state in which nitrogen intake exactly equals the sum of nitrogen losses so that the nitrogen content of the body remains constant. Nonis and Gous (2008) and Bonato et al. (2011) defined nitrogen balance as the point at which the difference between nitrogen intake and nitrogen excretion is zero. Yet, nitrogen equilibrium may also be defined as the point at which there is no growth, no body protein accretion, or no amino acid accretion (Sakomura and Coon, 2003). There are some questions as to whether whole-body protein accretion or amino acid accretion would be more suitable for maintenance requirement determination. Some argue that shifts in whole-body amino acid composition at low protein/amino acid intakes may underestimate the true value of amino acid maintenance requirements (Edwards et al., 1999). Nevertheless, there is strong evidence that using nitrogen balance (excretion) underestimates protein and amino acid maintenance requirements (Laflamme and Hannah, 2013). Laflamme and Hannah (2013) state that nitrogen balance studies do not factor in changes to body composition or health caused by low protein intake, nor do they take into account prior nutritional status or current energy status.

Another key limitation of attempts to quantify maintenance requirements is the reliance on the

Received April 9, 2015.
Accepted August 13, 2015.
[1]Current address: Dow AgroSciences, LLC, Indianapolis, IN.
[2]Current address: Winnepeg, Manitoba, Canada R3T 3W9.
[3]Current address: Departamento de Zootecnia - Faculdade de Ciências Agrárias e Veterinárias, UNESP/Campus de Jaboticabal, Jaboticabal/SP, Brazil.
[4]Corresponding author: ccoon@uark.edu

Table 1. The quantity of each crystalline amino acid added to the basal diet for each dietary treatment.

	Treatment[a]				
	1	2	3	4	5
	Amino Acid%[b]				
Met	0	0.038	0.076	0.114	0.152
Arg	0	0.11	0.22	0.33	0.44
Lys	0	0.1	0.2	0.3	0.4
Leu	0	0.109	0.218	0.327	0.436
Phe	0	0.065	0.13	0.195	0.26
Ile	0	0.073	0.146	0.219	0.292
Thr	0	0.074	0.148	0.222	0.296
Val	0	0.082	0.164	0.246	0.328
His	0	0.032	0.064	0.096	0.128

[a]Each row represents one assay.

[b]Added to basal diet.

Table 2. Ingredient and amino acid mixture of basal diet.

Basal diet[1]		Amino acid mixture[2]	
Ingredients	%	Crystalline amino acid	%
Corn starch	Up to 100	L-Glutamate	3.13
Sucrose	17.00	L-Glycine	0.80
Corn oil	6.50	L-Alanine	0.95
Solka floc	7.96	L-Methionine[5]	0.15
Dicalcium phosphate	2.22	L-Cysteine	0.14
Magnesium sulfate	0.35	L-Arginine[5]	0.44
Potassium carbonate	0.35	L-Lysine-HCl[5]	0.40
Sodium chloride	0.30	L-Leucine[5]	0.44
Choline choride-60	0.26	L-Isoleucine[5]	0.29
Sodium bicarbonate	0.20	L-Phenylalanine[5]	0.26
Vitamin mixture[3]	0.13	L-Tyrosine	0.23
Mineral mixture[4]	0.06	L-Threonine[5]	0.30
Ethoxyquin	0.02	L-Valine[5]	0.33
Amino acid mixture[2]	8.06	L-Histidine-HCl-H_2O[5]	0.13
		L-Tryptophan	0.07

[1]Contained 3,506 kcal ME/kg, 6.78% protein equivalents from crystalline amino acids and 0.49% Ca.

[2]Amino acid mixture according to 40% NRC (1994) recommendation.

[3]Provided per kilogram of diet: vitamin A, 13,200 IU; vitamin E, 66 IU; vitamin D_3, 4,950 ICU; niacin, 74.25 mg; D-pantothenic acid, 33 mg; riboflavin, 19.8 mg; pyridoxine, 5,000 mg; thiamine, 3.3 mg; menadione, 3.3 mg; folic acid, 3.3 mg; biotin, 0.33 mg; vitamin B_{12}, 0.0297 mg.

[4]Provided per kilogram of diet: Manganese, 180 mg; Zinc, 150.6 mg; Iron, 20.16 mg; Copper, 2.04 mg; Iodine, 1.26 mg; Se, 0.3 mg.

[5]Indicates omission of this amino acid only from the basal diet for its requirement determination.

rooster or young chick to extrapolate the maintenance requirement of the hen. The purpose of this study was to determine the maintenance requirements of broiler breeder hens for Arg, His, Ile, Leu, Lys, Met, Phe, Thr, and Val for non-laying broiler breeder hens using protein accretion.

MATERIALS AND METHODS

General Procedures

Ten assays were conducted to determine maintenance requirements for methionine, lysine, arginine, leucine, isoleucine, phenylalanine, threonine, valine, and histidine in the broiler breeder hen.

The comparative slaughter technique (Wolynetz and Sibbald, 1987; Heger et al., 2008) was used to determine protein accretion. Initial body composition data were obtained from 20 randomly selected birds for each experimental weight group: small (2,167 g), medium (2,355 g) and large (2,465 g). For each assay, 50 non-photostimulated, 23-wk-old Cobb 500 broiler breeder hens of similar body weight were housed in individual cages (47 cm × 30.5 cm × 47 cm) in environmentally controlled rooms (∼22°C) with a 8-hr light : 16-hr dark period light schedule. Ten birds were assigned to each of 5 dietary treatments for a 3-d acclimation period and a 21-d experimental period. Five purified diets were formulated to contain graded amounts of the test amino acid ranging from 0 to 40% of the total NRC (1994) suggested requirement (Table 1). The basal diet was formulated to contain 3,506 kcal ME/kg, 6.78% of CP equivalents from crystalline amino acids, 0.49% Ca to impede ova development, and all essential amino acids according to 40% of amino acids recommended by NRC (1994) (Table 2). At the conclusion of the 21-d experimental period, feed was removed for a 36-h period. Birds were then euthanized by CO_2 asphyxiation and stored at –4°C for later analysis.

Analytical Procedures

The 20 "initial" birds plus 8 birds from each dietary treatment were autoclaved in an AMSCO 3053 sterilizer (Steris Corporation, Mentor, OH) at 120°C for 16 hours and homogenized in a Waring 4L blender (Waring products division, Dynamics Corporation of America, New Hartford, CT). Subsamples were frozen at –20°C and lyophilized in a Genesis SQ 12 EL Freeze drier (The Virtis Company, Gardiner, NY) prior to dry matter and nitrogen analyses. Dry matter was determined as a percentage of total wet carcass weight. Whole-body protein (Kjeldahl N) was analyzed on freeze-dried samples by Method 990.03 – Combustion Method (AOAC, 1995) by the University of Arkansas Central Analytical Laboratory.

Statistical Analysis

The experiment design was a one factor completely randomized design. Linear regression models were fitted using JMP Pro 11 (SAS Institute, Cary, NC) with an individual bird serving as the experimental unit. The 3 linear regression equations generated were: Protein accretion (g/bird/day) vs. AA intake (mg/bird/day), Protein accretion (g/kg$^{0.75}$ BW/day) vs. AA intake (mg/kg$^{0.75}$/day), and Protein accretion (g/kg protein mass/day) vs. AA intake (mg/kg protein mass/day). A valid model was considered one with significant slope and intercept parameter estimates. Significance was considered $P < 0.05$. Amino acid requirements for maintenance (i.e., zero protein) were calculated as the x-intercept.

RESULTS

Linear regressions were generated for protein accretion as a function of amino acid intake and the slope and y-intercept were verified as statistically significant (Tables 3–12). Maintenance requirements are summarized in Table 13. At zero protein accretion, the estimated maintenance requirements for Arg are 315 mg/d, 173 mg/kg$^{0.75}$/d, and 650 mg/kgCP/d. The requirements for isoleucine were determined to be 164 mg/d, 93 mg/kg$^{0.75}$/d, and 328 mg/kgCP/d. The requirements for leucine were determined to be 82 mg/d, 51 mg/kg$^{0.75}$/d, and 172 mg/kgCP/d. The requirements for lysine were determined to be 145 mg/d, 81 mg/kg$^{0.75}$/d, and 295 mg/kgCP/d. The methionine requirements were determined to be 112 mg/d, 60 mg/kg$^{0.75}$/d, and 223 mg/kgCP/d. The phenylalanine requirements were determined to be 259 mg/d, 125 mg/kg$^{0.75}$/d, and 524 mg/kgCP/d. The threonine requirements were determined to be 262 mg/d, 133 mg/kg$^{0.75}$/d, and 477 mg/kgCP/d. The valine requirements were determined to be 312 mg/d, 154 mg/kg$^{0.75}$/d, and 545 mg/kgCP/d. The point of zero accretion for histidine was beyond the range of the experimental histidine intakes. Thus, the histidine requirement could not be accurately predicted. Amino acid composition of initial broiler breeders can be seen in Table 14.

DISCUSSION

Using nitrogen balance has been found to underestimate protein and amino acid maintenance requirements (Laflamme and Hannah, 2013). Some have argued that the point of zero protein accretion also underestimates the maintenance requirement since the total body protein may be constant, or accreting, but the amino acid in question may still be limiting (Edwards et al., 1999). However, it can also be argued that if at the higher amino acid intake—the level at which amino acid accretion is zero—there is positive protein accretion, i.e., growth, then that level cannot, by definition, be maintenance. The present study defined maintenance as the point of zero protein accretion. The present study also does not suffer from the same limitations as other studies, i.e., using young chicks, extrapolation from production data, etc., that are the likely cause of the great variation of experimental results.

The present study reports maintenance requirements as a function of body protein as well as metabolic body weight and daily intake (Tables 3 and 4). Several authors have argued that reporting requirements on this basis may be more appropriate (Emmans and Oldham, 1988; Gous, 2007; Bonato et al., 2011) and provide for a more accurate comparison among studies and genetic strains. Amino acid requirements are not directly related to body weight, per se, because there is no amino acid cost in maintaining lipids, minerals, or water, and reporting maintenance requirements based on metabolic body weight does not take into account differences in body composition. As genetic selection for greater amounts of lean mass occurs, there will be a need to reassess maintenance requirements if body composition is not given consideration.

The present study determined the lysine requirements to be 145 mg/d, 81 mg/kg$^{0.75}$/d, or 295 mg/kgCP/d. Lys estimates for maintenance usually are relatively low values per unit of body mass compared to other amino acids, such as Met, possibly due to its

Table 3. Results of lysine maintenance requirement assay.

	Lysine							
	Feed intake	Lys intake			BW gain	Protein Accretion		
Lys%	g/d	mg/d	mg/kgCP/d	mg/kgBW$^{0.75}$/d	g/d/b	g/d	mg/kgCP/d	mg/kgBW$^{0.75}$/d
0.00	62.06	0.00	0.00	0.00	−4.00	−1.968	−1.165	−4.003
0.10	80.91	79.65	45.49	158.47	3.77	−1.632	−0.933	−3.300
0.20	106.22	212.44	116.39	397.50	12.30	0.500	0.272	0.874
0.30	109.00	327.00	175.91	603.00	17.06	1.177	0.625	2.061
0.40	109.00	436.00	235.43	811.85	16.56	0.752	0.406	1.390
Pooled SEM	2.84	22.6	44.6	12.7	1.22	0.73	0.21	0.38

Table 4. Results of arginine requirement assay.

	Arginine							
	Feed intake	Arg intake			BW gain	Protein accretion		
Arg%	g/d	mg/d	mg/kgCP/d	mg/kgBW$^{0.75}$/d	g/d/b	g/d	mg/kgCP/d	mg/kgBW$^{0.75}$/d
0.00	49.93	0.00	0.00	0.00	−10.80	−3.337	−2.069	−7.169
0.11	63.07	68.96	40.83	139.64	−5.71	−2.250	−1.338	−4.607
0.22	94.82	211.29	117.45	403.98	5.57	−0.851	−0.489	−1.738
0.33	103.83	342.76	188.33	651.49	12.52	0.161	0.087	0.273
0.44	109.00	479.60	262.72	902.00	14.68	0.512	0.281	0.943
Pooled SEM	3.50	25.1	52.60	14.5	1.51	0.74	0.20	0.34

Table 5. Results of methionine requirement assay.

	Methionine							
	Feed intake	Met intake			BW gain	Protein accretion		
Met%	g/d	mg/d	mg/kgCP/d	mg/kgBW$^{0.75}$/d	g/d/b	mg/d	mg/kgCP/d	mg/kgBW$^{0.75}$/d
0	59.48	0	0	0	–11.24	–11.95	–3.40	–5.40
0.038	70.32	26.72	54.40	15.65	–5.53	–5.46	–1.52	–2.49
0.076	99.96	75.97	141.37	41.26	6.10	3.03	0.91	1.70
0.114	108.77	124.00	238.12	64.26	14.88	0.40	0.11	0.24
0.152	109.00	165.68	309.40	86.56	13.95	2.92	0.83	1.58
Pooled SEM	3.35	8.73	18.40	5.02	1.59	4.58	0.20	0.32

Table 6. Results of leucine requirement assay.

	Leucine							
	Feed intake	Leu intake			BW gain	Protein accretion		
Leu%	g/d	mg/d	mg/kgCP/d	mg/kgBW$^{0.75}$/d	g/d/b	mg/d	mg/kgCP/d	mg/kgBW$^{0.75}$/d
0.000	37.09	0.00	0.00	0.00	–10.84	–0.834	–0.509	–1.672
0.109	63.29	71.58	42.56	142.22	–4.56	–1.028	–0.606	–2.051
0.218	99.04	218.16	119.57	409.25	12.05	0.229	0.127	0.402
0.327	107.10	349.53	192.07	653.42	15.79	1.301	0.716	2.396
0.436	108.84	474.48	255.92	886.29	16.88	0.676	0.365	1.213
Pooled SEM	4.26	25.10	50.00	14.10	1.69	0.59	0.18	0.32

Table 7. Results of valine requirement assay.

	Valine							
	Feed intake	Val intake			BW gain	Protein accretion		
Val%	g/d	mg/d	mg/kgCP/d	mg/kgBW$^{0.75}$/d	g/d/b	mg/d	mg/kgCP/d	mg/kgBW$^{0.75}$/d
0.000	47.40	0.00	0.00	0.00	–13.50	–3.577	–2.112	–6.851
0.082	69.39	56.90	32.11	103.42	–6.48	–2.355	–1.330	–4.310
0.164	98.19	161.03	87.33	281.94	7.91	–0.030	–0.021	–0.125
0.246	108.57	267.07	141.00	466.41	17.06	0.192	0.094	0.257
0.328	108.95	357.35	189.19	613.89	16.04	1.074	0.578	1.80
Polled SEM	3.76	18.80	35.40	10.40	1.84	0.69	0.21	0.36

Table 8. Results of isoleucine requirement assay.

	Isoleucine							
	Feed intake	Ile intake			BW gain	Protein accretion		
Ile%	g/d	mg/d	mg/kgCP/d	mg/kgBW$^{0.75}$/d	g/d/b	mg/d	mg/kgCP/d	mg/kgBW$^{0.75}$/d
0.000	43.55	0.00	0.00	0.00	–11.48	–2.502	–1.577	–5.462
0.073	59.68	44.81	27.04	92.05	–7.13	–2.296	–1.386	–4.737
0.146	89.10	135.52	77.49	268.73	6.08	–0.608	–0.350	–1.301
0.219	106.50	233.25	130.49	437.04	14.17	2.128	1.187	3.932
0.292	107.96	315.25	175.43	590.46	15.52	2.112	1.173	3.851
Pooled SEM	3.89	16.80	33.00	9.77	1.65	0.92	0.26	0.45

low rates of degradation (Leeson and Summers, 2001). Leveille and Fisher (1959) suggested the maintenance requirements for Lys for White Leghorn adult roosters was as low as 29 mg/kg/d. However, the researchers postulated that they could not truly determine the true Lys maintenance requirement due to positive nitrogen balance at zero Lys intake during a 5-d trial. The researchers utilized amino acid mixtures simulating egg protein as the basal and replaced various amounts of the test amino acid with equimolar amounts of nitrogen from glycine and glutamic acid. Gous et al. (1983) suggested the low Lys maintenance requirements reported by Leveille and Fisher (1959) were possibly inaccurate because of the experimental methods utilized. Nonis and Gous (2008) reassessed the Lys requirements and found that the maintenance requirement of an adult cockerel at zero N retention to be 37 mg/kgBW/d. Results based on the rooster appear to underestimate the lysine requirements of the broiler breeder hen. However, Fisher et al. (2001) conducted a Lys dose-response experiment with broiler breeder hens at 26, 37, 48, and 60 weeks of age rather than young chicks, and extrapolated maintenance requirement for zero Lys accretion to be near zero: 0.00, 0.02, 0.01, 0.01 mg/kg/d, respectively. In addition, Bowmaker and Gous (1991), in feeding experiments with broiler breeders, extrapolated the egg production response curve to zero (eggs) and reported the maintenance requirement for Lys was

Table 9. Results of threonine requirement assay.

	Threonine							
	Feed intake	Thr intake			BW gain	Protein accretion		
Thr%	g/d	mg/d	mg/kgCP/d	mg/kgBW$^{0.75}$/d	g/d/b	mg/d	mg/kgCP/d	mg/kgBW$^{0.75}$/d
0.000	49.30	0.00	0.00	0.00	–12.49	–2.736	–1.648	–5.383
0.074	67.18	47.28	27.33	88.64	–6.19	–2.270	–1.313	–4.298
0.148	92.60	138.60	75.31	245.61	4.60	–1.186	–0.654	–2.177
0.222	108.94	241.84	127.23	418.88	14.12	–0.320	–0.169	–0.619
0.296	108.92	322.40	171.31	558.36	16.92	1.122	0.588	1.720
Pooled SEM	3.63	17.10	31.30	9.42	1.71	0.87	0.26	0.45

Table 10. Results of phenylalanine requirement assay.

	Phenylalanine							
	Feed intake	Phe intake			BW gain	Protein accretion		
Phe%	g/d	mg/d	mg/kgCP/d	mg/kgBW$^{0.75}$/d	g/b/d	g/d	g/kgCP/d	g/kgBW$^{0.75}$/d
0.00	54.68	0.00	0.00	0.00	–7.64	–7.59	–4.38	–15.36
0.065	85.21	55.39	105.94	28.88	4.67	–6.5	–3.4	–12.76
0.13	107.44	139.67	231.43	68.47	13.69	0.6	0.27	0.80
0.195	108.82	212.19	387.10	103.28	17.12	–4.31	–2.11	–8.22
0.26	108.35	281.71	449.06	137.77	14.60	2.96	1.45	4.21
Pooled SEM	3.32	15.00	29.80	8.54	1.41	0.46	0.24	0.87

Table 11. Results of histidine requirement assay.

	Histidine							
	Feed intake	His intake			BW gain	Protein accretion		
His%	g/d	mg/d	mg/kgCP/d	mg/kgBW$^{0.75}$/d	g/d/b	mg/d	mg/kgCP/d	mg/kgBW$^{0.75}$/d
0.000	78.01	0.00	0.00	0.00	1.05	–2.025	–1.111	–3.648
0.032	96.60	30.86	16.71	55.12	7.30	–1.230	–0.673	–2.240
0.064	105.51	63.21	33.53	109.75	12.83	–0.088	–0.047	–0.174
0.096	108.07	103.65	54.42	178.15	15.37	0.179	0.102	0.306
0.128	108.12	138.12	72.60	239.14	14.63	–0.279	–0.144	–0.478
Polled SEM	1.86	7.07	13.10	3.74	0.90	0.43	0.12	0.23

11.2 mg/kg/d. Fisher et al. (2001) concluded that it was difficult to describe any precise biological meaning to the concept of amino acid requirements for maintenance when these are estimated by extrapolation of response curves.

Edwards et al. (1999) calculated Lys maintenance requirements of young chicks for a slow-growing strain and a fast-growing strain using zero protein accretion and zero Lys accretion. A higher lysine maintenance requirement was determined based on zero Lys accretion rather than zero protein accretion. Based on Lys accretion, Lys maintenance requirements were 114 mg/kg$^{0.75}$/d for the slow-growing strain and 89.1 mg/kg$^{0.75}$/d for the fast-growing strain. Leeson and Summers (2001) hypothesized that this higher difference is based on the premise that at zero nitrogen balance, the bird is still losing Lys although other amino acids are actually accreting. According to Edwards et al. (1999), this difference may be explained by the shift in the type of protein in the body, with more collagen protein and less contractile protein being present in chicks fed Lys levels near maintenance. Evidence stated by Edwards et al. (1999) suggested that a decrease of Lys concentration in whole-body protein is followed by an increase in proline and glycine (rich in collagen) concentrations. The Lys requirements in the present study based on protein accretion (81 mg/kg$^{0.75}$/d) in non-producing broiler breeders appear to be lower, but in general agreement (within 10%) with the maintenance requirements reported by Edwards et al. (1999) and Fisher (1998), respectively (89.1 mg/kg$^{0.75}$/d; 73 mg/kg/d) and within 15% of the value proposed by Sakomura and Coon (2003; 94.2 mg/kg$^{0.75}$/d). The lower Lys requirement may be partially explained by the lower whole-body lysine content within this study (Table 5) as compared with the profile presented by Fisher (1998).

Bae et al. (1999) affirmed that amino acid antagonisms may occur during a deficiency state and point to the dominant role of Leu in its interactions with Ile and Val. These observations also suggested that the maintenance requirements for Val are unlikely to remain constant and may be changed by the relative dietary proportions of the other 2 branched chain amino acids (Ile and Leu). In the present study, higher Val (154.1 mg/kg$^{0.75}$/d) and Ile (93.3 mg/kg$^{0.75}$/d) requirements were determined compared with other authors, regardless of methodology, whereas Leu was not consistently higher or lower compared with other authors (Table 4). The differences between the current findings

Table 12. Equations describing protein accretion as a function of amino acid intake in broiler breeder hens.

	mg/d		mg/kgBW$^{0.75}$/d		mg/kgCP/d	
	Protein Accretion (g/d)	R^2	Protein Accretion (g/kg$^{0.75}$/d)	R^2	Protein Accretion (g/kgCP/d)	R^2
Arg	–2.330639 + 0.0073839*AA intake (mg/d)	0.375	–1.452385 + 0.0083739*AA intake (mg/kg.75/d)	0.365	–5.127008 + 0.00788973*AA intake (mg/kgCP/d)	0.315
His*	–2.16674 + 0.0116406*AA intake (mg/d)	0.149	–1.160377 + 0.012841*AA intake (mg/kg.75/d)	0.157	–3.905961 + 0.0113285*AA intake (mg/kgCP/d)	0.117
Ile	–3.234291 + 0.0197581*AA intake (mg/d)	0.691	–2.094013 + 0.0224522*AA intake (mg/kg.75/d)	0.690	–7.199341 + 0.0219378*AA intake (mg/kgCP/d)	0.622
Leu	–0.465372 + 0.0057054*AA intake (mg/d)	0.256	–0.296994 + 0.0058085*AA intake (mg/kg.75/d)	0.214	–0.896112 + 0.00521790*AA intake (mg/kgCP/d)	0.192
Lys	–1.54392 + 0.0106561*AA intake (mg/d)	0.494	–0.916578 + 0.011329*AA intake (mg/kg.75/d)	0.485	–3.151671 + 0.010688*AA intake (mg/kgCP/d)	0.428
Met	–2.385947 + 0.0213982*AA intake (mg/d)	0.428	–1.559504 + 0.026062*AA intake (mg/kg.75/d)	0.443	–5.421527 + 0.0243249*AA intake (mg/kgCP/d)	0.393
Phe	–3.891837 + 0.0150239*AA intake (mg/d)	0.332	–2.157417 + 0.0171926*AA intake (mg/kg.75/d)	0.364	–6.970059 + 0.01331406*AA intake (mg/kgCP/d)	0.210
Thr	–4.550712 + 0.0173956*AA intake (mg/d)	0.547	–2.764736 + 0.0208258*AA intake (mg/kg.75/d)	0.577	–8.752371 + 0.0183375*AA intake (mg/kgCP/d)	0.436
Val	–4.007557 + 0.0128441*AA intake (mg/d)	0.570	–2.429375 + 0.0157624*AA intake (mg/kg.75/d)	0.609	–7.764664 + 0.0142408*AA intake (mg/kgCP/d)	0.532

*X-intercept is outside of assay range, thus, the histidine requirement could not be accurately predicted.

Table 13. Calculated amino acid maintenance requirements of broiler breeder hens.

	Current Findings			Fisher (1998)	Fisher et al. (2001)	Nonis and Gous (2008)	Leveille[1]	Edwards[2]	Hruby (1998)
	Breeder					Rooster		Broiler chick	
	mg/d	mg/kgBW$^{0.75}$/d	mg/kgCP/d	mg/kgBW/d				mg/kgBW$^{0.75}$/d	
Arg	315.6	173.4	650.8	50			120		104
Ile	163.7	93.3	328.2	50		60[3]	72		56
Leu	81.6	51.1	171.7	32			124		38
Lys	144.9	80.9	294.9	73	0 – 0.02	37	29	89.1 – 114	0
Met	111.5	59.8	222.9	25			90	9.4 – 15.3	19
Phe	259.0	125.5	523.5	16			60		27
Thr	261.6	132.8	477.3	40		56	74	45.7	31
Val	312.0	154.1	545.2	60			61	32.4 – 48.8	36

[1]Studies from Leveille and Fisher (1959, 1960a, 1960b).
[2]Studies from Edwards et al. (1997, 1999).
[3]Burnham and Gous (1992).

Table 14. Whole-body amino acid composition of broiler breeders.

	Current Findings	Fisher (1998)
	g/16g N	
Arg	6.3	6.8
Ile	4.1	4.0
Leu	7.2	7.1
Lys	6.2	7.5
Met	1.9	2.5
TSAA	3.8	3.6
Phe	3.8	4.0
Phe + Tyr	6.1	7.1
Thr	4.0	4.2
Val	4.9	4.4

and previous results may be caused by the imbalance between these amino acids in the purified diets (Bae et al., 1999). The higher Val requirements may also be due to higher whole-body Val content (Table 5) compared with Fisher (1998). Similarly, the Arg, Phe, and Thr requirements in the present study were higher than the values proposed by other authors. Fractional degradation rates, the rate at which skeletal muscle degrades, have been observed to increase in broiler breeder hens at the onset of sexual maturity (Ekmay et al., 2013). Furthermore, Tesseraud et al. (2000) found differences in fractional degradation rates between broiler strains in young birds but not in the older birds of the same strains, indicating a possible age effect. Although, the exact amino acid profile of the endogenous losses of the breeder hen is unknown, the losses are likely greater as compared with the broiler chick and the rooster: resulting in the greater maintenance requirements observed. Met requirements were also determined to be higher than the values proposed by Fisher (1998), and Hruby (1998) in the breeder and broiler, respectively, but not in the rooster (Leveille and Fisher, 1960b). The whole-body Met content presented here is lower than the content reported by Fisher (1998). This is not surprising given that Straková et al. (2002) found age-related differences in the methionine content of 3 hybrid broiler strains, and likely contributes to the different requirements determined among authors.

Increased protein degradation at the onset of sexual maturity and differing whole-body amino acid composition contributes to the overall amino acid requirement of the hen, and likely explains the equal or higher maintenance requirements of the broiler breeder hen when compared with the young chick or the mature rooster.

REFERENCES

AOAC. 1995. Protein (Crude) in Animal Feed (Combustion Method). Method 990.03. 16th Edn., Vol. 2.
Bae, S. H., J. H. Ki, I. S. Shin, and K. I. Han. 1999. Partition of amino acid requirement of broilers between maintenance and growth. V Isoleucine and valine. Asian-Australas. J. Anim. Sci. 12:381–387.
Bonato, M.A., N.K. Sakomura, J.C. Siqueira, J. B. K. Fernandes, and R.M. Gous. 2011. Maintenance requirements for methionine and cysteine, and threonine for poultry. S. Afr. J. Anim. Sci. 41:209–222.
Bowmaker, J. E., and R. M. Gous, 1991. The response of broiler breeder hens to dietary lysine and methionine. Br. Poult. Sci. 32:1069–1088.
Burnham, D., and R. M. Gous. 1992. Isoleucine requirements of the chicken: requirement for maintenance. Br. Poult. Sci. 33:59–69.
Edwards, H. M., III, D. H. Baker, S. R. Fernandez, and C. M. Parsons. 1997. Maintenance threonine requirement and efficiency of its use for accretion of whole-body threonine and protein in young chicks. Br. J. Nutr. 78:111–119.
Edwards, H. M., III, S. R. Fernandez, and D. H. Baker. 1999. Maintenance lysine requirements and efficiency of using lysine for accretion of whole-body lysine and protein of young chicks. Poult. Sci. 78:1412–1417.
Ekmay, R. D., C. Salas, J. England, S. Cerrate, and C. N. Coon. 2013. The effects of age, energy and protein intake on protein turnover and the expression of proteolysis-related genes in the broiler breeder hen. Comp. Biochem. Physiol. B Biochem. Mol. Biol. 164:38–43.
Emmans, G. C., and J. D. Oldham. 1988. Modelling of growth and nutrition in different species. Pages 13–21 in Modelling of Livestock Production Systems. S. Karver, and J. A. M. Van Arendonk, eds. Kluwer Academic Publishers, Dordrecht.
Fisher, C. 1998. Amino acid requirements of broiler breeders. Poultry Sci. 77:124–133.
Fisher, C., R. Gous, and L. Goddard. 2001. Lysine requirements of broiler breeder hens. Proc. Aust. Poult. Sci. Sym. 183–186.
Fuller, M. F. 1994. Amino acid requirements for maintenance, body protein accretion and reproduction in pigs. Pages 155–184 in Amino acids in Farm Animal Nutrition. J. P. F. D'Mello, ed. CAB International, Wallingford, UK.
Fuller, M. F., R. Mcwilliam, T. C. Wang, and L. R. Giles. 1989. The optimum dietary amino acid pattern for growing pigs. Br. J. Nutr. 62:255–267.
Gous, R. M., C. Fisher, and L.A. Broadbent. 1984. Measurements of the amino acid requirement for maintenance of adult cockerels. Proc. XVII World's Poult. Congress, Helsinki, Finland.
Gous, R. M., 2007. Methodologies for modeling energy and amino acid responses in poultry. Braz. J. Anim. Sci. 36:263–274.
Gous, R. M., C. Fisher, and L. A. Broadbent, 1983. The maintenance requirement for lysine of adult male fowls. World's Poult. Sci. J. 39:239–240.
Heger, J., P. Patrás, S. Nitrayová, J. Karcol, and P. Dolesová. 2008. Lysine maintenance requirement and efficiency of its utilisation in young pigs as estimated by comparative slaughter technique. Arch Anim Nutr. 62:182–92.
Hruby, M. 1998. The amino acid maintenance and growth requirements of male broilers. Ph.D. thesis, University of Minnesota, Minnesota, US.
Laflamme, D. P., and S. S. Hannah. 2013. Discrepancy between use of lean body mass or nitrogen balance to determine protein requirements for adult cats. J. Feline Med. Surg. 15:691–697.
Leeson, S., and J. D. Summers. 2001. Nutrition of the Chicken. 4th ed. University Books, Guelph, Canada.
Leveille, G. A., and H. Fisher. 1959. Amino acid requirements for maintenance in the adult rooster II. The requirements for glutamic acid, histidine, lysine and arginine. J. Nutr. 69:289–294.
Leveille, G.A., and H. Fisher. 1960a. Amino acid requirements for maintenance in the adult rooster III. The requirements for leucine, isoleucine, valine and threonine, with reference also to the utilisation of the D-isomers of valine, threonine, and isoleucine. J. Nutr. 70:135–140.
Leveille, G. A., and H. Fisher. 1960b. Amino acid requirements for maintenance in the adult rooster IV. The requirements for methionine, cysteine, phenylalanine, tyrosine and tryptophan; the adequacy of the determined requirements. J. Nutr. 72:8–15.
National Research Council. 1994. Nutrient Requirements of Poultry. 9th rev. ed. National Academy Press, Washington, DC.
Nonis, M. K., and R. M. Gous. 2008. Threonine and lysine requirements for maintenance in chickens. S. Afr. J. Anim. Sci. 38:75–82.
Sakomura, N. K., and C. Coon, 2003. Amino acid requirements for maintenance of broiler breeder pullets. Pages 280–281 in World's Poultry Science, 14th European Symposium on Poultry Nutrition. Lillehammer, Norway.
Straková, E., P. Jelínek, P. Suchý, and M. Antonínová. 2002. Spectrum of amino acids in muscles of hybrid broilers during prolonged feeding. Czech J. Anim. Sci. 47:519–526.
Tesseraud, S., A. M. Chagneau, and J. Grizard. 2000. Muscle protein turnover during early development in chickens divergently selected for growth rate. Poult. Sci. 79:1465–1471.
Wolynetz, M. S., and I. R. Sibbald. 1987. Need for Comparative Slaughter Experiments in Poultry Research. Poult. Sci. 66: 1961–1972.