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Effect of varying dietary concentrations of lysine on growth performance of the Pearl Grey guinea fowl

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ABSTRACT Lysine is the second limiting essential amino acid in poultry nutrition after methionine. Understanding the lysine requirement of poultry is necessary in guiding formulation of least cost diets that effectively meet the nutritional needs of individual birds. The lysine requirement of the Pearl Grey guinea fowl (PGGF) is not known. Therefore, the objective of this study was to assess the appropriate lysine levels required for optimal growth attributes of the PGGF. In a 12-week study, 512 one-day-old Pearl Grey guinea keets were weighed individually and randomly assigned to electrically heated battery brooders. Each battery contained 12 compartments housing 15 birds each. Eight diets fed to the experimental birds consisted of corn-soybean meal and contained 0.80 to 1.22 digestible lysine in 0.06% increments. Feed and water were provided at free choice and the diets were replicated twice. Experimental diets contained 3,100 Kcal metabolizable energy (ME)/kg diet and 23% crude protein (CP), 3,150 ME Kcal ME/kg diet and 21% CP, and 3,100 ME/kg and 17% CP, at zero to 4, 5 to 10, and 11 to 12 weeks of age (WOA), respectively. Birds were provided water ad libitum and a 23:1 and 8:16-hr (light:dark) regimen at zero to 8 and 9 to 12 WOA, respectively. Birds were weighed weekly, and body weight gain, feed consumption, and feed conversions were determined. Data were analyzed using the General Linear Model (GLM) procedures of SAS (2002) with dietary lysine as treatment effect. Females responded better to diets containing 1.04 and 0.8% lysine from hatch to 4 and 5 to 12 WOA, respectively. Males responded better to diets containing 1.10 and 0.8% lysine at hatch to 4 WOA and 5 to 12 WOA, respectively. Therefore, we recommend that PGGF females and males be fed diets containing 1.04 and 1.10%, respectively, at hatch to 4 WOA and 0.80% lysine at 5 to 12 WOA. The diets should be supplied in phases.

Key words: lysine, Pearl Grey guinea fowl, amino acids, growth performance

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INTRODUCTION

Poultry is a major source of protein worldwide and contributes significantly to the economy of the United States and other parts of the world. However, the availability and cost of poultry and poultry products are highly dictated by consumer demand and cost, which is associated with the efficiency of production. Also, cultural preferences are associated with the demand for various poultry species, such as the guinea fowl. In the United States and Europe, the demand for guinea fowl meat has increased in recent years because of its unique characteristics as specialty poultry meat and also due to its nutritional value (Embury, 2001; Nahashon et al., 2004). Previously research also showed that guinea fowl meat is more nutritious when compared with chicken and is high in protein and essential fatty acids (Agwunobi and Ekpenyong, 1990; Laudadio et al., 2012). Previous reports also demonstrated that guinea fowl meat contains less abdominal fat (Nahashon et al. 2005) and cholesterol (Bulinskin and Szydlowsha, 1970) when compared with chickens (Hrdinka et al., 1996). On the other hand Kilonzo-Nthenge et al. (2008) and Mathis and McDougald (1987) also have demonstrated that the guinea fowl was less susceptible to poultry diseases when compared with chickens. These characteristics and the demand for specialty poultry meat justify the need to continue to improve production efficiency of the guinea fowl, hence minimizing the cost of production, increasing profitability, and affordability to the consumer.

Feeding constitutes 65 to 75% of the total cost of poultry production, and guinea fowl is no exception. Thus, it is very important to design and formulate feeds that can be utilized more efficiently by complementing the bird's genetic potential. It may be argued that the current nutrient specifications for chickens and turkeys

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may be utilized for the guinea fowl; however, recent studies have shown that genetic similarity between the Pearl Grey guinea fowl and the Single Comb White Leghorn chicken is as low as 31.3% (Nahashon et al., 2010). Also, the requirement for protein and metabolizable energy differed significantly from that of chickens and turkeys (Nahashon et al., 2005, 2006, and 2007). In the current study, it was hypothesized that the requirement for lysine by the Pearl Grey guinea fowl would be lower than that of chickens and turkeys. In the absence of nutrient specifications for the guinea fowl, they are fed turkey rations whose crude protein is in excess of the dietary needs of the guinea fowl (Nahashon et al., 2005, 2006). The ages from hatch to 12 wk of age is considered a critical developmental period for guinea keets, and therefore essential nutrients must be supplied in adequacy to assure profitability in the guinea fowl production enterprise.

The crude protein requirements for the Pearl Grey guinea fowl have been established (Nahashon et al., 2005, 2006). Lacking, however, is the optimum requirement for lysine, an essential amino acid that is most limiting for growth or body weight gain in poultry. At present, guinea fowls are fed expensive turkey rations that contain 1.6 and 1.5% digestible lysine at zero to 4 and 4 to 8 wk of age, respectively (NRC, 1994). Lysine is the second-most limiting amino acid in standard diets of poultry after methionine. It is not adequately supplied in corn-soy based diets of poultry and the body cannot synthesize it; therefore, it must be supplemented in the diet. Lysine is also considered a reference amino acid in the ideal protein concept (Pack, 1995; Silva et al., 2005) and it plays a vital role in growth, carcass characteristics, and feed conversion in poultry. Further, lysine also supports muscle tissue formation and produces antibodies and enzymes that are essential in overall growth of the bird. Previous reports demonstrate that optimum dietary levels of lysine affect the amino acid balance and dietary protein levels in poultry (Morris et al., 1987; Abebe and Morris, 1990; Abdel-Maksoud, et. al., 2010). Excess of these limiting amino acids such as lysine also can cause amino acid imbalance and increase feeding cost. Alternatively, determining and utilizing optimum concentrations of these amino acids could reduce feed cost or increase economic efficiency (Alagawany and Mahrose, 2014). Therefore, the goal of this research was to evaluate the lysine requirement for the Pearl Grey guinea fowl. It was hypothesized that by controlling for all environmental factors, optimum dietary level of lysine would be determined to be lower than that provided in turkey rations that are routinely fed to the Pearl Grey guinea fowl.

MATERIALS AND METHODS

This research was reviewed and approved by the Institutional Animal Care and Use Committee. The trial was conducted from August through November 2014.

Birds and Dietary Treatments

Five-hundred-and-twelve one-day-old Pearl Grey guinea keets (256 males and 256 females) were purchased from Ideal Poultry Farms (Ideal Poultry Breeding Farms, Inc., Cameron, TX). These birds were randomly assigned to 8 dietary treatments in a completely randomized design. The dietary treatments comprised total digestible lysine concentrations ranging from 0.80 to1.22% in increments of 0.06%. The control diet contained the 1.10% lysine, which was estimated from lysine requirement of Single Comb White Leghorn chickens (NRC 1994). The starter diets were isocaloric (3,100 Kcal/kg ME) and isonitrogenous (23% CP) and were fed from hatch to 4 wk of age (**WOA**), Table 1. During the growing period (5 to 10 WOA), the digestible lysine concentrations were maintained the same in the 8 dietary treatments; however, the grower rations contained 3,150 Kcal/kg ME and 21% CP (Table 2). At 11 to 12 WOA, birds were fed diets containing 3,100 kcal ME/kg of diet and 17% CP (Table 3). The diets were formulated to contain sufficient levels of methionine, cysteine, threonine, and tryptophan. Methionine was incorporated at least at 2.16% of the crude protein content of the respective diets. Recent reports on evaluation of methionine requirement of the French guinea fowl (Johnson, 2015) indicated that these birds require less Met + Cys than chickens (0.8% vs. 0.9, in 23% CP diets). The French guinea fowl is meat-type and larger than the Pearl Grey variety, and the nutrient requirements tend to be higher than those of the Pearl Grey. Bell and Weaver (2002) suggested that in order for birds to attain optimum growth at an economical scale, key nutrients such as energy and protein must be phased to justify requirement and to produce the bird at the lowest cost possible. The dietary concentrations of ME and CP fed to the Pearl Grey guinea fowl in this study were previously reported by Nahashon et al. (2006). During the accelerated growth phase (5 to 10 WOA), the demand for energy is higher hence the ME was increased from 3,100 to 3,150 Kcal/kg diet. Thereafter at 10 to 12 WOA growth rate was slower, as expected, hence the need to minimize caloric consumption by reducing the ME (3,100 Kcal/kg diet) and weight gain of the Pearl Grey guinea fowl. Each dietary treatment was replicated 2 times with 16 birds per replicate. Feed was provided in mash form and both feed and water were provided at free choice throughout the study period. Mortality was recorded and monitored daily as it occurred.

Management of Experimental Birds

At one d old, the experimental birds were wing banded, weighed, and assigned to electrically heated, temperature controlled Petersime^{TM} battery brooders (Petersime brooders model 2SD12, Petersime Incubator Co., Gettysburg, OH) for the first 4 WOA. The battery brooders were equipped with raised wire floors;

Table 1. Composition of experimental diets fed from hatch to 4 wks of age, %.

Lysine concentration (%)	0.8	0.86	0.92	0.98	1.04	1.10	1.16	1.22
Ingredient	(%)							
Corn (8% CP)	50.67	50.67	50.10	49.30	49.23	48.95	48.93	49.21
Soybean meal (47.5% CP)	14.10	17.00	19.80	22.58	25.70	29.40	29.40	30.81
Corn gluten meal (60% CP)	17.60	15.80	13.70	11.70	9.60	7.12	7.12	6.00
Wheat middlings	10.36	8.62	8.27	8.15	6.58	5.14	5.14	4.40
Alfalfa meal (17% CP)	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Poult. Blend. Fat (8158 Kcal ME/kg)	2.30	2.70	3.10	3.60	4.00	4.50	4.50	4.62
Dicalcium phosphate (18% P,22% Ca)	1.74	1.75	1.75	1.74	1.77	1.74	1.74	1.73
Calcium carbonate (38% Ca)	1.45	1.40	1.30	1.30	1.48	1.50	1.50	1.45
D, L-Methionine (98%)[1]	0.03	0.05	0.06	0.08	0.09	0.10	0.10	0.12
Arginine	0.20	0.29	0.23	0.00	0.00	0.00	0.00	0.00
Threonine	0.00	0.15	0.12	0.00	0.00	0.00	0.00	0.00
Valine	0.00	0.02	0.02	0.00	0.00	0.00	0.00	0.00
Lysine Hcl	0.00	0.00	0.00	0.00	0.00	0.00	0.02	0.11
Sodium chloride	0.30	0.30	0.30	0.30	0.30	0.30	0.30	0.30
Vitamin-mineral premix[2]	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25
Calculated levels								
ME (Kcal/Kg)	3,103	3,104	3,101	3,103	3,103	3,103	3,103	3,100
CP, %	23.02	23.01	23.04	23.09	23.05	23.02	23.07	23.04
Calcium, %	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Total phosphorous, %	0.73	0.73	0.73	0.73	0.73	0.73	0.73	0.73
Available phosphorous, %	0.45	0.45	0.45	0.45	0.45	0.45	0.45	0.45
Cysteine, %	0.40	0.40	0.40	0.40	0.40	0.40	0.40	0.40
Methionine, %	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50
Methionine + Cysteine, %	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90
Arginine, %	1.30	1.30	1.30	1.30	1.30	1.30	1.30	1.30
Threonine, %	0.83	0.82	0.84	0.83	0.83	0.84	0.82	0.83
Tryptophan, %	0.22	0.22	0.22	0.22	0.22	0.22	0.22	0.22
Lysine, %	0.80	0.86	0.92	0.98	1.04	1.10	1.16	1.22
Analyzed levels (%)								
Crude protein	22.96	23.03	23.06	22.95	23.07	22.98	22.96	23.04
Crude fat	4.91	5.20	5.51	5.90	6.19	6.56	6.56	6.64
Total lysine	0.90	0.97	1.04	1.10	1.18	1.24	1.31	1.37

[1]Degussa Corporation, Kennesaw, GA.

[2]Provided per kilogram of diet: retinyl acetate, 3500 IU; cholecalciferol, 1000 ICU; DL-α-tocopheryl acetate, 4.5 IU; menadione sodium bisulfite complex, 2.8 mg; vitamin B_{12}, 5.0 mg; riboflavin, 2.5 mg; pantothenic acid, 4.0 mg; niacin, 15.0 mg; choline, 172 mg; folic acid, 230 mg; ethoxyquin, 56.7 mg; manganese, 65 mg; iodine, 1 mg; iron, 54. mg; copper, 6 mg; zinc, 55 mg; selenium, 0.3 mg.

they measured 99 x 66 x 25 cm and each housed 16 birds. The brooders were used to provide artificial heat for the birds and the temperature was kept at 32°C for the first wk and was gradually reduced by 2.8°C to a steady temperature of 23.9°C, and from this point on no artificial heating was provided to the experimental birds. At 5 WOA the guinea keets were transferred into growing battery cages, which were not supplied with supplemental heating. However constant room temperature was maintained at 21°C. The cages measured 163 x 69 x 33 cm and each housed 8 birds from 5 to 12 WOA. Birds were provided a 23-hour light regimen from hatch to 8 WOA and thereafter 8 h light, which was stepped up by one h weekly until 12 WOA. Ventilation within the brooders and growing cages was maintained by thermostatically controlled exhaust fans.

Measurements and Statistical Analysis

Experimental birds were weighed prior to assignment to dietary treatments and thereafter weekly until 12 WOA. Weekly body weight and feed consumption from which body weight gains and feed conversion ratios were determined were measured. Data were analyzed by the ANOVA option of GLM of the SAS/STAT software 9.2.1(SAS Institute, 2002) with lysine concentration as a main effect. The following statistical model was used for body weight gain, feed consumption, and feed conversion ratio:

$$Y_{ijklm} = \mu + L_i + S_j + T_k + (LS)ij + (LT)_{ik} + (ST)_{jk} + (LST)_{ijk} + R_{ijkl} + y_{ijklm}$$

where Y_{ijklm} represents the response variables from each individual replication, μ represents the overall mean, L_i represents the effect of dietary lysine, S_j represents the effect of sex, T_k represents the effect of time in wk, $(LS)_{ij}$ represents the effect due to interaction between lysine and sex, $(LT)_{ik}$ represents the effect due to interactions between lysine and time, $(ST)_{jk}$ represents the effect due to interactions between sex and time, $(LST)_{ijk}$ represents the effect due to interactions among lysine, sex, and time, R_{ijkl} represents the inter-experimental unit (replications) error term, and γ_{ijklm} represents the intra-experimental unit error term. When there is a significant F-value, means were separated using the Least Square means option. Differences in mortality

Table 2. Composition of experimental diets fed from 5 to 10 WOA, %.

Lysine concentration (%)	0.8	0.86	0.92	0.98	1.04	1.10	1.16	1.22
Ingredient				(%)				
Corn (8% CP)	64.11	57.78	61.14	60.40	60.45	56.73	56.20	55.85
Soybean meal (47.5% CP)	16.40	17.10	22.20	24.20	24.70	31.00	33.80	34.28
Corn gluten meal (60% CP)	13.00	12.00	8.90	7.40	7.00	2.50	0.51	0.13
Wheat middlings	0.98	6.00	1.00	0.76	0.44	0.91	0.22	0.20
Alfalfa meal (17% CP)	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Poult. Blend. Fat (8158 Kcal ME/kg)	1.10	2.70	2.45	2.90	3.00	4.55	5.00	5.20
Dical. Phosphate(18% P,22% Ca)	1.35	1.35	1.33	1.33	1.34	1.30	1.27	1.27
Calcium carbonate (38% Ca)	1.40	1.40	1.37	1.36	1.35	1.35	1.33	1.33
D, L-Methionine (98%)[1]	0.03	0.04	0.06	0.07	0.08	0.11	0.12	0.12
Arginine	0.07	0.04	0.00	0.00	0.00	0.00	0.00	0.00
Threonine	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Lysine Hcl	0.01	0.04	0.00	0.03	0.09	0.00	0.00	0.07
Sodium chloride	0.30	0.30	0.30	0.30	0.30	0.30	0.30	0.30
Vitamin-mineral premix[2]	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25
Calculated levels								
ME (Kcal/Kg)	3,152	3,151	3,152	3,152	3,153	3,151	3,150	3,152
CP, %	21.03	21.01	21.09	21.05	21.00	21.06	21.06	21.02
Calcium, %	0.901	0.900	0.900	0.900	0.90	0.90	0.90	0.90
Total phosphorous, %	0.599	0.624	0.603	0.604	0.604	0.607	0.602	0.602
Available phosphorous, %	0.353	0.357	0.354	0.355	0.357	0.356	0.351	0.351
Cysteine, %	0.381	0.380	0.372	0.368	0.366	0.357	0.352	0.351
Methionine, %	0.452	0.451	0.454	0.453	0.460	0.459	0.455	0.452
Methionine + Cysteine, %	0.834	0.831	0.827	0.822	0.827	0.816	0.808	0.803
Arginine, %	1.137	1.148	1.185	1.222	1.228	1.357	1.408	1.416
Threonine, %	0.760	0.760	0.770	0.760	0.770	0.760	0.760	0.790
Tryptophan, %	0.210	0.210	0.210	0.210	0.210	0.210	0.210	0.210
Lysine HCl, %	0.80	0.86	0.92	0.98	1.04	1.10	1.16	1.22
Analyzed levels, %								
Crude protein	21.07	21.10	21.03	20.98	21.11	20.99	21.04	21.06
Crude fat	3.97	5.30	5.03	5.38	5.46	6.68	7.02	7.18
Total lysine	0.91	0.97	1.03	1.07	1.15	1.22	1.29	1.35

[1]Degussa Corporation, Kennesaw, GA.

[2]Provided per kilogram of diet: retinyl acetate, 3500 IU; cholecalciferol, 1000 ICU; DL-α-tocopheryl acetate, 4.5 IU; menadione sodium bisulfite complex, 2.8 mg; vitamin B_{12}, 5.0 mg; riboflavin, 2.5 mg; pantothenic acid, 4.0 mg; niacin, 15.0 mg; choline, 172 mg; folic acid, 230 mg; ethoxyquin, 56.7 mg; manganese, 65 mg; iodine, 1 mg; iron, 54 mg; copper, 6 mg; zinc, 55 mg; selenium, 0.3 mg.

among lysine concentrations were analyzed using the chi-square method. Significance implies ($P < 0.05$) unless stated otherwise. The optimal level of dietary lysine was confirmed by estimating the response of birds to lysine through BW gain and FCR using the response surface regression model (**RSREG**, SAS command) of SAS (SAS Institute, 2002; Ahmadi and Golian, 2011).

RESULTS AND DISCUSSION

Interactions among lysine concentrations, sex, and time (wk) were significant ($P < 0.05$), and, therefore, means were separated by lysine concentrations, sex, and time. Mean feed consumption of Pearl Grey guinea fowl females and males fed diets varying in concentrations of digestible lysine are presented in Table 4. As expected, feed consumption increased with age of the guinea fowl. In most part, feed consumption of the birds increased proportionately with increase in dietary digestible lysine. Even though the increase in feed consumption was in some cases not significant between some lysine concentration, there was strong evidence that transitioning from the low lysine diets (0.8%) to the high lysine (1.22%) diets significantly increased feed consumption of the guinea fowl ($P < 0.05$). For instance at zero to 4 WOA females fed the 0.8, 0.98, 1.10, and 1.16% lysine diets consumed 424, 731, 773, and 838 g of feed/bird, respectively. Likewise at zero to 4 WOA males fed the 0.8, 0.98, 1.10, and 1.22% lysine diets consumed 392, 624, 720, and 782 g of feed/bird, respectively. On the other hand, the increase in feed consumption as a result of increase in lysine concentration also was more pronounced at lower concentrations of lysine than the higher concentrations. For instance, at 5 to 10 WOA females fed diets containing 0.86% digestible lysine consumed 28% more feed than those fed diets containing 0.8% digestible lysine. However, at this same age period, birds fed 1.22% digestible lysine consumed only 6% more feed than birds fed diets containing 1.16% digestible lysine. There is the likelihood that the low (0.8%) lysine diets had a higher propensity to create a state of deficiency in the experimental birds such that any small amounts of lysine supplementation would stimulate feed consumption in an attempt to overcome the deficiency. These observations are consistent with previous reports that high lysine levels in monogastrics such as pigs had a positive response to feed consumption (Baker et al., 1975). According to Rezaeil et al. (2004), increasing dietary lysine significantly ($P < 0.05$) increased feed consumption in starter (hatch to 4 WOA), and weight

Table 3. Composition of experimental diets fed from 11 to 12 WOA, %.

Lysine concentration (%)	0.80	0.86	0.92	0.98	1.04	1.10	1.16	1.22
Ingredient, %	(%)							
Corn (8% CP)	64.20	66.52	67.56	63.60	64.00	63.94	67.41	68.20
Soybean meal (47.5% CP)	23.00	23.40	24.00	24.00	23.50	23.50	24.00	24.00
Corn gluten meal (60% CP)	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.13
Wheat middlings	5.00	2.00	1.00	4.00	4.00	4.00	1.00	0.20
Alfalfa meal (17% CP)	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Poult. Blend. Fat (8158 Kcal ME/kg)	3.40	3.70	3.10	4.00	4.00	4.00	3.00	2.80
Dicalcium phosphate (18% P,22% Ca)	1.35	1.35	1.33	1.33	1.34	1.30	1.27	1.27
Calcium carbonate (38% Ca)	1.40	1.40	1.37	1.36	1.35	1.35	1.33	1.33
D, L-Methionine (98%)[1]	0.03	0.04	0.06	0.07	0.08	0.11	0.12	0.12
Arginine	0.07	0.04	0.00	0.00	0.00	0.00	0.00	0.00
Threonine	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Lysine Hcl	0.00	0.00	0.03	0.09	0.18	0.25	0.32	0.40
Sodium chloride	0.30	0.30	0.30	0.30	0.30	0.30	0.30	0.30
Vitamin-mineral premix[2]	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25
Calculated levels								
ME (Kcal/Kg)	3,105	3,106	3,108	3,105	3,107	3,102	3,104	3,111
CP, %	17.14	17.06	17.28	17.41	17.21	17.20	17.27	17.29
Calcium, %	0.924	0.92	0.90	0.90	0.90	0.89	0.87	0.87
Total phosphorous, %	0.615	0.599	0.593	0.608	0.607	0.600	0.582	0.578
Available phosphorous, %	0.363	0.357	0.353	0.358	0.359	0.352	0.342	0.340
Cysteine, %	0.302	0.300	0.303	0.305	0.302	0.302	0.302	0.303
Methionine, %	0.315	0.325	0.349	0.358	0.365	0.394	0.407	0.409
Methionine + Cysteine, %	0.618	0.626	0.652	0.663	0.668	0.697	0.710	0.712
Arginine, %	1.184	1.143	1.117	1.137	1.121	1.121	1.117	1.113
Threonine, %	0.66	0.66	0.66	0.66	0.66	0.66	0.66	0.66
Tryptophan, %	0.22	0.22	0.22	0.22	0.22	0.22	0.22	0.22
Lysine HCl, %	0.0	0.0	0.03	0.09	0.18	0.25	0.32	0.4
Analyzed levels, %								
Crude protein	17.07	16.92	16.98	17.01	17.05	17.12	16.98	17.02
Crude fat	5.90	6.18	5.65	6.40	6.40	6.40	5.56	5.39
Total lysine	0.89	0.96	1.02	1.09	1.14	1.21	1.27	1.33

[1]Degussa Corporation, Kennesaw, GA.
[2]Provided per kilogram of diet: retinyl acetate, 3500 IU; cholecalciferol, 1000 ICU; DL-α-tocopheryl acetate, 4.5 IU; menadione sodium bisulfite complex, 2.8 mg; vitamin B_{12}, 5.0 mg; riboflavin, 2.5 mg; pantothenic acid, 4.0 mg; niacin, 15.0 mg; choline, 172 mg; folic acid, 230 mg; ethoxyquin, 56.7 mg; manganese, 65 mg; iodine, 1 mg; iron, 54. mg; copper, 6 mg; zinc, 55 mg; selenium, 0.3 mg.

Table 4. Feed consumption of Pearl Grey guinea fowl females fed diets varying in lysine concentrations from hatch to 12 wk of age.

	Lysine concentration (%)									
WOA[1]	0.80	0.86	0.92	0.98	1.04	1.10	1.16	1.22	SEM[2]	Prob[3]
	Females (g/bird)									
0 to 4	423.6[g]	635.6[e]	598.6[f]	730.5[d]	820.8[b]	773.0[c]	838.1[a]	776.2[c]	5.8	$P < 0.01$
5 to 10	2583.7[e]	3295.0[d]	3341.7[d]	3757.4[b,c]	3764.0[b,c]	3702.2[c]	3835.4[b]	4045.7[a]	30.5	$P < 0.01$
11 to 12	1568.2[f]	1876.5[b]	1734.7[c]	1641.1[d,e]	1613.2[e]	1728.0[c]	1657.7[d]	2058.8[a]	12.2	$P < 0.01$
Total	4575.5[g]	5807.1[e]	5675.0[f]	6129.0[d]	6198.0[c]	6203.2[c]	6331.2[b]	6880.7[a]	34.6	$P < 0.01$
	Males (g/bird/)									
0 to 4	391.7[g]	497.7[e]	465. 1[f]	623.5[d]	688.1[c]	719.7[b]	684.9[c]	782.1[a]	5.1	$P < 0.01$
5 to 10	2646.3[f]	2844.8[e]	2656.3[f]	3383.3[a]	3305.1[c]	3344.3[b]	3325.4[b,c]	3266.3[d]	13.8	$P < 0.01$
11 to 12	1573.4[d]	1553.7[d]	1380.0[f]	1462.5[e]	1625.6[c]	1616.6[c]	1656.6[b]	1682.2[a]	8.5	$P < 0.01$
Total	4611.4[f]	4896.2[e]	4501.4[g]	5469.3[d]	5618.8[c]	5680.6[b]	5666.9[b]	5730.6[a]	15.7	$P < 0.01$

[a–g]Within sex, means within rows with no common superscripts differ significantly ($P < 0.05$).
[1]Weeks of age.
[2]Pooled Standard error mean (N = 2).
[3]Probability.

gain and feed to gain ratio during the grower period. It also was noted in this study that the response to increasing dietary concentration of lysine was higher at early age (zero to 4 WOA) than later (5 to 10 WOA). At zero to 4 WOA, the increase in feed consumption observed in birds fed diets containing 1.22% lysine when compared with those fed 0.8% lysine was 83% in females and 99% in males. At 5 to 10 WOA, the increase in feed consumption of birds fed diets containing 1.22% lysine when compared with those fed 0.8% lysine

Table 5. Lysine consumption of Pearl Grey guinea fowl fed diets varying in lysine concentrations from hatch to 12 wk of age.

	Lysine concentration (%)									
WOA[1]	0.80	0.86	0.92	0.98	1.04	1.10	1.16	1.22	SEM[2]	Prob[3]
	Females (g/bird)									
0 to 4	3.39[f]	5.5[e]	5.5[e]	7.2[d]	8.5[c]	8.5[c]	9.7[a]	9.5[b]	0.05	$P < 0.01$
5 to 10	20.7[h]	28.3[g]	30.7[f]	36.8[e]	39.1[d]	40.7[c]	44.5[b]	49.4[a]	0.29	$P < 0.01$
11 to 12	12.5[e]	16.1[d]	16.0[d]	16.1[d]	16.8[c]	19.0[b]	19.2[b]	25.1[a]	0.13	$P < 0.01$
Total	36.6[f]	49.9[e]	52.2[e]	60.1[d]	64.4[c,d]	68.2[b,c]	73.4[b]	84.0[a]	0.38	$P < 0.01$
	Males (g/bird)									
0 to 4	3.1[f]	4.3[e]	4.3[e]	6.1[d]	7.2[c]	7.9[b]	7.9[b]	9.5[a]	0.05	$P < 0.01$
5 to 10	21.2[g]	24.5[f]	24.4[f]	33.2[e]	34.4[d]	36.8[c]	38.6[b]	39.9[a]	0.14	$P < 0.01$
11 to 12	12.6[g]	13.4[f]	12.7[g]	14.3[e]	16.9[d]	17.8[c]	19.2[b]	20.5[a]	0.09	$P < 0.01$
Total	36.9[e]	42.2[d]	41.4[d]	53.6[c]	58.5b[c]	62.5[b]	65.7[a,b]	69.9[a]	0.24	$P < 0.01$

[a–h]Within sex, means within rows with no common superscripts differ significantly ($P < 0.05$).
[1]Weeks of age.
[2]Pooled Standard error mean (N = 2).
[3]Probability.

Table 6. Body weight gains of Pearl Grey guinea fowl pullets fed diets varying in lysine concentrations from hatch to 12 wk of age.

	Lysine concentration (%)									
WOA[1]	0.80	0.86	0.92	0.98	1.04	1.10	1.16	1.22	SEM[2]	Prob[3]
	Females (g/bird)									
0 to 4	168.9[d]	283.0[c]	283.2[c]	341.9[b]	414.2 [a]	403.9 [a]	436.6 [a]	451.4[a]	14.4	$P < 0.01$
5 to 10	841.3[c]	1060.7[b]	1152.0[a]	1169.6[a]	1101.4[a,b]	1132.3[a,b]	1111.8[a,b]	1163.4[a]	30.8	$P < 0.01$
11 to 12	450.5[a]	409.9[a,b]	381.7[b,c]	327.5[c]	175.9[e]	361.1[c]	402.7[b]	269.0[d]	15.9	$P < 0.01$
Total	1460.7[d]	1753.6[c]	1816.9[b]	1839.0[b]	1691.5[c]	1897.3[a]	1951.1[a]	1883.8a[b]	35.6	$P < 0.01$
	Males (g/bird)									
0 to 4	115.0[e]	204.6[d]	202.8[d]	282.2[c]	308.9[c]	346.5[b]	345.9[b]	401.1[a]	10.5	$P < 0.01$
5 to 10	872.5[b]	896.4[b]	891.1[b]	1044.1[a]	1029.7[a]	998.0[a,b]	1025.2[a]	945.5[b]	27.2	$P < 0.01$
11 to 12	350.1[a]	303.2[b]	278.0[b,c]	224.8[c]	282.3[b,c]	262.9[c]	243.5[c]	310.5[b]	13.9	$P < 0.01$
Total	1337.6[d]	1404.2[c]	1371.9[c,d]	1551.1[b]	1620.9[a]	1607.4[a,b]	1614.6[a]	1657.1[a]	31.2	$P < 0.01$

[a–e]Within sex, means within rows with no common superscripts differ significantly ($P < 0.05$).
[1]Weeks of age.
[2]Pooled Standard error mean (N = 2).
[3]Probability.

was 57% in females and 23% in males. Therefore, females consumed more feed as a result of the increase in dietary lysine concentrations than males, and, also, such response was higher at an early age (hatch to 4 WOA) than later (5 to 10 and 11 to12 WOA).

Mean lysine consumption of Pearl Grey guinea fowl females and males fed varying concentrations of digestible lysine are presented in Table 5. For the most part, consumption of lysine increased with increase in dietary concentration of lysine and the mean differences in lysine consumption among these dietary lysine concentrations were significant ($P < 0.05$). Lysine consumption of female Pearl Grey guinea fowl fed the 1.04 and 1.22% lysine diets was 150 and 180% higher than that of birds fed diets containing 0.8% lysine, respectively, at zero to 4 WOA. At 5 to 10 WOA females on 1.04 and 1.22% lysine consumed 88 and 138% more lysine than those fed the 0.8% lysine diets. A similar pattern of lysine consumption was observed in male Pearl Prey guinea fowl; however, the percent change in lysine consumption of birds fed the 1.22% and those fed the 0.80% lysine was significantly lower than in females. As expected, lysine consumption also was increased with increase in age of the Pearl Grey guinea fowl. This was consistent with the increase in feed consumption as these birds aged (Table 4). These findings are in agreement with previous reports of Bateman et. al. (2008) that increased dietary concentrations of lysine were associated with both an increase in feed and lysine utilization. The positive and significant correlations between dietary lysine concentrations and both lysine and feed consumption (Table 8) further support these observations.

The body weight gains of Pearl Grey (**PG**) guinea fowl fed diets containing varying concentrations of lysine are presented in Table 6. The PG guinea fowl pullets fed diets containing 1.04 to 1.22% lysine had higher BWG than those fed all other dietary lysine concentrations at zero to 4 WOA ($P < 0.05$). For instance at zero to 4 WOA the BWG of pullets fed the 1.22% lysine diets were 32 and 168% higher than those of pullets fed the 0.98 and 0.80% lysine diets, respectively.

Table 7. Feed conversion ratios of Pearl Grey guinea fowl males and females fed diets varying in lysine concentrations from hatch to 12 wk of age.

WOA[1]	Lysine concentration (%) 0.80	0.86	0.92	0.98	1.04	1.10	1.16	1.22	SEM[2]	Prob[3]
	Females (g feed/g BWG)									
0 to 4	2.74[a]	2.35[b]	2.27[b,c]	2.21[b,c]	2.07[c,d]	2.00[c,d]	2.00[c,d]	1.81[d]	0.10	$P < 0.01$
5 to 10	3.28[a,b]	3.22[a,b]	3.03[b]	3.27[a,b]	3.45[a]	3.31[a,b]	3.48[a]	3.43[a]	0.10	$P < 0.01$
11 to 12	3.57[d]	4.77[b]	4.59[b,c]	5.01[a,b]	5.12[a]	4.86[b]	4.18[c]	4.97[b,c]	0.20	$P < 0.01$
Average	3.20[d]	3.45[b]	3.30[c]	3.50[b]	3.55[b]	3.39b[c]	3.22[d]	3.40[b,c]	0.18	$P < 0.01$
	Males (g feed/g BWG)									
0 to 4	3.68[a]	2.53[b]	2.40[b,c]	2.29[b,c]	2.28[b,c]	2.12[c]	2.02[c]	2.01[c]	0.10	$P < 0.01$
5 to 10	3.09[b]	3.39[a,b]	3.05[b]	3.29[a,b]	3.24[a,b]	3.48[a]	3.28[a,b]	3.41[a,b]	0.12	$P < 0.01$
11 to 12	4.56[d]	5.22[c]	4.61[d]	5.53[b,c]	5.67[b]	6.59[a]	6.65[a]	5.23[c]	0.15	$P < 0.01$
Average	3.78[b]	3.71[c,b]	3.35[e]	3.70[c]	3.73[b]	4.06[a]	3.98[a,b]	3.55[d]	0.18	$P < 0.01$

[a–e]Within sex, means within rows with no common superscripts differ significantly ($P < 0.05$).
[1]Weeks of age.
[2]Pooled Standard error mean (N = 2).
[3]Probabilit.

Table 8. Correlation coefficients of lysine and performance parameters of Pearl Grey guinea fowl females and males fed diets varying in lysine concentrations from hatch to 12 WOA.

	Lysine[2]	BW0-4	BW5-10	BW11-12	FCR0-4	FCR5-10	FCR11-12
Lys Cons[1]	0.889**	0.864**	0.741**	0.434*	− 0.594*	− 0.412*	− 0.113
Lysine[2]		0.714**	0.638**	0.365	− 0.460*	− 0.255	− 0.017
BW 0 to 4			0.749**	0.272	− 0.495*	− 0.428*	− 0.348*
BW 5 to 10				0.289	− 0.480*	− 0.551*	− 0.027
BW 11 to 12					− 0.222	− 0.131	− 0.496**

**($P < 0.01$); *($P < 0.05$); BW: Body weight; FCR: Feed conversion ratio.
[1]Lysine consumption.
[2]Lysine concentration in diet.

On the other hand, at 5 to 10 WOA guinea fowl of either sex fed diets containing 0.92 to 1.22% of lysine diets exhibited superior body weight gains when compared to those fed other dietary lysine concentrations. At 11 to 12 WOA, for the most part differences in BWG of pullets fed diets containing 0.8 to 0.86% lysine did not differ significantly ($P > 0.05$); however, they were higher than those of pullets fed the 0.98 to 1.22% lysine diets. This observation implies that the demand for lysine is higher at an early age than later. A recent report of Payne et. al. (2015) suggested that dietary lysine concentration may influence signaling pathways regulating food intake in brain-liver axis via glutamate synthesis. The increase in feed consumption as a result of increase in dietary lysine concentration translated into an increase in body weight gain of PG guinea fowl. At zero to 4 WOA, BWG of females fed the 0.98% lysine were 104 and 21% higher than those of birds fed the 0.80 and 0.86% lysine diets, respectively. On the other hand, at the same age period, BWG of males fed the 0.98% lysine diets were 145 and 38% higher than those of birds fed the 0.80 and 0.86% lysine diets, respectively. At 11 to 12 WOA birds fed diets containing 0.80 to 0.86% lysine showed significantly higher ($P < 0.05$) BWG than birds fed the 0.92 to 1.22% lysine diets. These observations were consistent with reports of Labadan et. al. (2001), which cited evidence that requirements for lysine by broiler chickens were higher at the starter than grower and finisher periods. Previous studies on BWG of chickens also indicate that diets supplemented with amino acids help to improve carcass quality (Fancher & Jensen, 1989). Supplementation of chicken diet with lysine also has been shown to increase breast yield. Leclercq, (1998) reported that lysine is used in broiler production to improve body protein accretion specifically targeting development of breast muscle fibers. In this study, it was evident that both male and female Pearl Grey guinea fowl had higher BWG with increments of dietary lysine, especially during the accelerative growth phase such that zero to 4 WOA > 5 to 10 WOA > 11 to 12 WOA. These observations were consistent with the positive and significant correlations that were observed in this study between dietary lysine concentrations and body weight gain (Table 8).

Mean feed conversion ratios of PG guinea fowl females fed diets containing the various dietary concentrations of lysine are presented in Table 7. At zero to 4 WOA, birds that were fed the 1.04 to 1.22% lysine diets had significantly lower and better feed conversion ratios when compared to those fed diets containing 0.80 to 0.98% lysine ($P < 0.05$). The average feed conversion ratio of birds fed the 1.04 to 1.22% lysine diets at zero to 4 WOA was 2.07, 2.00, 2.00, and 1.81, respectively. On the other hand, the average feed conversion ratio of birds fed the 0.80 to 0.98% lysine diets at zero to 4 WOA was 2.74, 2.35, 2.27, and 2.21, respectively. Therefore, at zero to 4 WOA feed conversion ratios of birds fed either 1.16 or 1.22% lysine diets were 51 and 37% lower ($P < 0.05$) than those of birds fed the 0.8 lysine diets, respectively. These observations are supported by the higher body weight gain of the birds on the 1.14 to 1.22% lysine diets even though with higher feed consumption. This study is in agreement with previous reports in which higher weight gains and better feed conversion ratios were attributed to increased levels of digestible lysine supplementation in the diets of 21- to 40-day-old broilers (Viola et. al., 2009). As birds advance in age, their requirement and demand for nutrients such as lysine decrease, as was the case in this study. At 5 to 10 WOA, for the most part, differences in feed conversion ratios of birds fed the diets containing the various concentrations of lysine (0.8 to 0.98%) were significantly lower ($P < 0.05$) than those fed the 1.04 to 1.22% lysine diets. This may suggest a transitional period between the high and low demand and requirement for this amino acid by the PG guinea fowl. On average, at 11 to 12 WOA, feed conversion ratios of birds fed diets containing the 0.8 to 0.98% lysine were significantly lower ($P < 0.05$) and better than those of birds fed the 1.04 to 1.22% lysine diets ($P < 0.05$). The average feed conversion ratios of birds fed the 0.8 lysine at 11 to 12 WOA was 43% lower than those fed the 1.22% lysine diets.

The mean feed conversion ratios of Pearl Grey guinea fowl males fed diets containing the various dietary concentrations of lysine also are presented in Table 7. At zero to 4 WOA, birds that were fed the 1.10 to 1.22% lysine diets exhibited feed conversion ratios that were on average 28% lower and better ($P < 0.05$) than those of birds fed diets containing 0.80 to 1.04% lysine, respectively. At 5 to 10 and 11 to 12 WOA, birds fed the 0.80 to 0.98% lysine diets had significantly lower feed conversion ratios when compared to those fed other lysine diets ($P < 0.05$). Earlier reports of Martinez and Knabe (1990), which were in agreement with our observations, revealed that increasing dietary lysine concentrations increased daily feed to gain in broiler males. Similar to observations made with the females, male PG guinea fowl had almost a similar transitional trend from higher demand for lysine at an early age (zero to 4 WOA) to lower demand at a later age beginning at 6 WOA. These observations are in agreement with reports of Corzo et al. (2002) that increasing dietary lysine concentrations in diets of broiler chickens from 0.75 to 1.15% improved feed conversion ratio even after 6 WOA. Earlier findings (Kidd et al., 1998 and Dozier et al., 2008) using Ross broiler breeders also cited evidence that supplemental or increase in dietary amino acid resulted in an improvement of growth, feed conversion, and meat yield. This study is also consistent with previous reports in which higher weight gains and better feed conversion ratios were reported as a result of increased dietary concentrations of digestible lysine in diets of 21- to 40-day-old broilers (Mack et. al., 1999, Viola et. al., 2009). Also consistent with these observations were negative correlations reported in this study between dietary lysine concentrations and body weight gain. These correlations were observed at an early age and they were negative and significant ($P < 0.05$), Table 8.

Correlation coefficients of lysine and performance parameters of PG guinea fowl males and females fed diets varying in lysine concentrations from hatch to 12 WOA are presented in Table 8. As expected, correlations between dietary lysine concentration and lysine consumption (0.889) by the PG guinea fowl were positive and highly significant ($P < 0.01$). On the other hand, both dietary lysine concentrations and lysine consumption showed positive and significant correlations with body weight gain from hatch to 4 WOA ($P < 0.01$). However, these correlations were not observed at a later age, after 8 WOA, suggesting that these birds responded to increase in dietary lysine concentrations at an early age, especially during the accelerated growth phase. Feed conversion ratios at 2 to 4 WOA were negatively correlated with dietary lysine concentration and lysine consumption. As expected, BWG at the end of each wk of this study also were found to be negatively correlated with corresponding feed conversion ratios. For instance, at zero to 4 WOA the correlations between BWG and FCR at zero to 4, 5 to 10 and 11 to 12 WOA were −0.495, −0.428, and −0.348, respectively.

Response surface methodology utilizes statistical algorithms to predict optimum levels of utilization of nutrients such as lysine. The method was employed in this study to confirm optimal dietary lysine for the PG guinea fowl. With fixed BW at 6.5 WOA, both female and male guinea fowl utilized 1.04% lysine diets more efficiently, yielding BWG of about 195 to 200 g/bird/wk and FCR of 2 to 2.5 g feed/g BWGain (Figure 1A and 1B, respectively). On the other hand, a 3-dimensional response surface of the PG guinea fowl females with BW fixed at 6.5 WOA confirmed that 0.98% dietary lysine concentration was efficiently utilized yielding BWG of about 183 to 186 g/bird/wk and FCR of 2.8 to 3.0 g feed/g BWG. According to Mehri et al. (2012), response surface analysis has accurately predicted optimum amino acid required for growth and feed conversion in poultry. Response surface analysis also has been used in predicting dietary level of lysine for optimal BWG and FCR and also helps to understand the relation among response variables (Bas and Boyaci, 2007; Nuran, 2007).

In conclusion, suboptimal dietary lysine concentrations significantly decreased feed consumption in both male and female PG guinea fowl. While the optimum dietary lysine for the PG guinea fowl was determined to be less than that of turkeys, sex differences in response to the dietary lysine concentrations also was also observed. It also was determined that the requirement for lysine varies with age and therefore it should be supplied in phases. The lysine concentrations and regiments seem also to vary based on need, either for BWG or FCR. To achieve optimum BWG in females, the

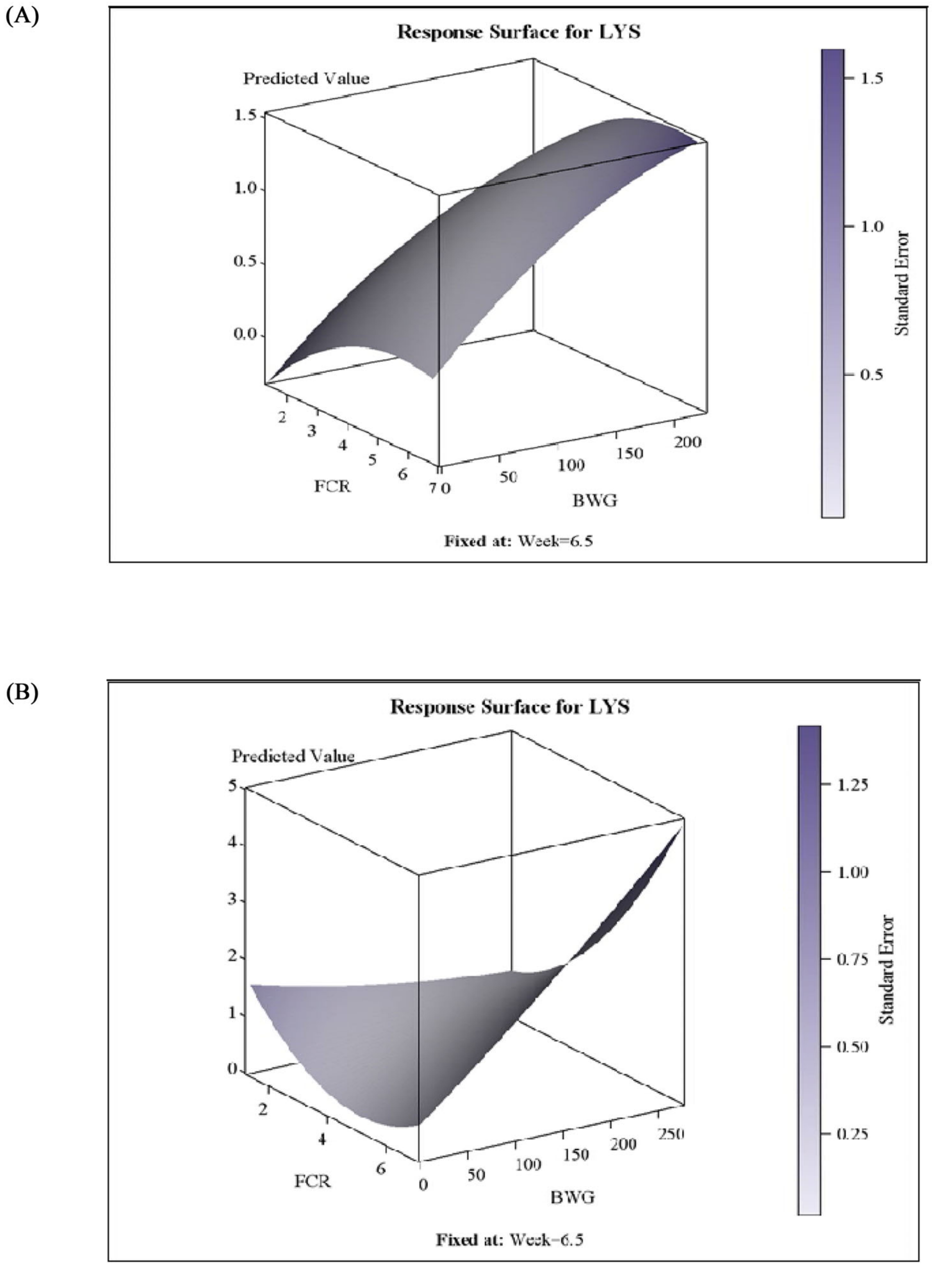

Figure 1. Response surface plot of Lysine (3-dimensional) for BWG (g/bird/wk) and FCR (g feed/g BWG) of male (A) and female (B) Pearl Grey guinea fowl ($P < 0.01$; age was held at 6.5 wk). Standard error of means increased with increase in BWG as denoted by increase in intensity of the response surface and the error bar. Predicted value refers to dietary lysine concentration. N = 2 observations per treatment.

minimum dietary lysine concentration should be 1.04% at zero to 4 WOA, 0.92% at 5 to 10 WOA, and 0.8% at 11 to 12 WOA. To attain optimum BWG in males of the PG guinea fowl, the minimum dietary lysine concentration should be 1.22% at zero to 4 WOA, 0.98% at 5 to 10 WOA, and 0.80% at 11 to 12 WOA. To achieve optimum FCR in females, the minimum level of dietary lysine should be 1.04% at zero to 4 WOA, 0.80 at 5 to 10 WOA, and 0.80 at 11 to 12 WOA. On the other hand, to attain optimum FCR, males would require dietary concentrations of lysine ranging from 1.10% at zero to 4 WOA and 0.8% at 5 to 12 WOA. These findings will guide standardization of lysine concentrations in diets of the Pearl Grey guinea fowl.

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