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Gompertz-Laird model prediction of optimum utilization of crude protein and metabolizable energy by French guinea fowl broilers

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ABSTRACT This study was conducted to assess the influence of dietary CP and ME on growth parameters of the French guinea fowl, a meat-type variety. In a 2 × 3 × 3 factorial arrangement, 297 one-day-old French guinea keets (162 females and 135 males) were randomly assigned to experimental diets comprising 3,050, 3,100, and 3,150 kcal of ME/kg, each containing 21, 23, and 25% CP from hatch to 4 wk of age (WOA), and 3,100, 3150, and 3,200 kcal of ME/kg, each containing 19, 21, and 23% CP at 5 to 8 WOA. Using BW and G:F data from hatch to 8 WOA, the Gompertz-Laird growth model was employed to estimate growth patterns of the French guinea fowl. Mean differences in exponential growth rate, age of maximum growth, and asymptotic BW among dietary CP and ME levels were not significant. However, instantaneous growth rate and weight at inflection point were significantly higher ($P < 0.05$) in birds on the 25% CP diet than those on the 21% CP diet at hatch to 4 WOA (1.12 kg/wk and 0.79 kg vs. 1.04 kg/wk and 0.74 kg, respectively). The exponential growth rate was also higher ($P < 0.05$) in birds fed the 3,050 kcal of ME/kg diet with either 23 or 25% CP than those fed diets containing 3,050 kcal of ME/kg and 21% CP. Mean G:F was higher ($P < 0.05$) in birds fed diets containing 3,050 kcal of ME/kg and either 21 or 23% CP than those in other dietary treatments. Therefore, based on the Gompertz-Laird growth model estimates, feeding 21 and 23% CP and 3,100 kcal of ME/kg at hatch to 4 WOA and 19 and 21% CP with 3,150 kcal of ME/kg at 5 to 8 WOA can be recommended as adequate for growth for the French guinea fowl broilers.

Key words: French guinea fowl, crude protein, metabolizable energy, Gompertz-Laird model

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INTRODUCTION

The French variety of guinea fowl is raised primarily for meat. Their growth rate lags that of broiler chickens partly due to lack of adequate information on their growth characteristics under various planes of nutrition. The carcass yield of guinea broilers at 12 wk of age (**WOA**) is about 77% (Hughes and Jones, 1980). Determination of nutrient requirements of different types of poultry is necessary to efficiently use the genetic potential of these birds for specific production goals (Pym, 1990). Several studies have evaluated the ME and CP requirements of the guinea fowl (Hughes and Jones, 1980; Sales and Du Preez, 1997; Nahashon et al., 2006a) with varying results.

Although recent reports have highlighted the growth pattern of the French variety of guinea fowl, information on the dietary CP and ME levels that would ensure optimum performance of these birds is limited. It is therefore necessary to study the growth pattern of French guinea fowl broiler under various planes of nutrition to provide guidelines to formulating least cost rations for optimum performance.

Dietary CP and ME have been suggested to be the key inputs that control broiler growth trajectory (Aerts et al., 2003). In addition, mathematical models of growth in poultry have played a key role in poultry improvement programs. The general importance of mathematical models of growth and their utilization in poultry have been emphasized (Anthony et al., 1991; Knížetová et al., 1991; Aggrey, 2002) especially when growth interacts with nutritional components (Aggrey, 2004). The application of mathematical growth models in combination with feed consumption data is important in bioeconomical studies because cumulative feed consumption up to slaughter weight is dependent on both growth rate and the shape of the growth curve (Pasternak and Shalev, 1983). Linear programming and dose response models have been employed extensively in evaluating requirements of essential nutrients of poultry (Aerts et al., 2003; Timmler and Rodehutscord,

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2003; Samadi and Liebert, 2006). Earlier report of Hruby et al. (1996) emphasized adequate description of bird growth and body composition using growth curves as a requirement for accurate assessment of nutrient requirement of broiler chickens.

Recently, Nahashon et al. (2006b) demonstrated the Gompertz-Laird model as a best fit in predicting growth patterns of the guinea fowl. This model was therefore chosen to predict the required dietary levels of CP and ME for optimum growth performance of the French guinea fowl broiler. The purpose of this study was to employ the Gompertz-Laird model to simultaneously estimate the required ME and CP for optimum performance of the growing French guinea broiler.

MATERIALS AND METHODS

Birds and Management

A total of 297 one-day-old randombred guinea keets (162 females and 135 males) of the French variety were obtained from Ideal Poultry Breeding Farms (Cameron, TX). Birds were weighed individually and randomly assigned to electrically heated, thermostatically controlled Petersime battery brooders (Petersime, Zulte, Belgium) equipped with raised wire floors from hatch to 4 WOA. The battery cages measuring 99 × 66 × 25 cm were partitioned into 2 compartments each measuring 99 × 33 × 25 cm and each compartment housed either 5 males or 6 female French guinea fowl. At 1 d of age, the brooder temperature was maintained at 32.2°C for the first week and was reduced gradually by 2.8°C every week until 23.9°C and from this point on, no artificial heating was provided to the birds. At 5 WOA, the keets were transferred into growing batteries that were not supplied with supplemental heating. Room temperature was maintained at 21.1°C. The growing batteries measured 162 × 34 × 33 cm and each housed either 5 males or 6 female French guinea fowl from 5 to 8 WOA. Ventilation within the growing cages was maintained by thermostatically controlled exhaust fans. The birds received 23 h of constant lighting from hatch to 8 WOA.

Dietary Treatments

Birds were randomly assigned to 9 dietary treatments in a 2 × 3 × 3 factorial arrangement with sex, CP, and ME as main effects. The dietary treatments fed at hatch to 4 WOA comprised 3,050, 3,100, and 3,150 kcal of ME/kg of diet each in combination with 21, 23, and 25% CP (Table 1). The TSAA:lysine for the 19, 21, and 23% CP diets was 70, 69, and 67%, respectively. Vieira et al. (2004) reported optimum performance of broiler chickens fed diets with TSAA:lysine of 62 to 69%. Also, Si et al. (2004) reported better feed conversions in broilers whose diets were fortified only to meet the methionine needs rather than TSAA. Methionine was maintained at 2.16% of the dietary CP content. These diets were adjusted to contain 3,100, 3,150, and 3,200 kcal of ME/kg of diet each in combination with 19, 21, and 23% CP, respectively, and were fed from 5

Table 1. Composition of experimental diets (%) fed 0 to 4 wk of age

Item	3,050/21[1]	3,100/21	3,150/21	3,050/23	3,100/23	3,150/23	3,050/25	3,100/25	3,150/25
Ingredients (%)									
Corn, yellow #2 (8% CP)	59.63	58.35	57.00	53.80	52.32	51.02	47.51	46.20	44.81
Soybean meal (48% CP)	30.42	30.60	30.90	35.32	35.70	35.90	40.60	40.81	41.10
Alfalfa meal	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Meat and bone meal (50% CP)	3.00	3.00	3.00	3.00	3.00	3.00	3.00	3.00	3.00
Poultry blended fat	2.90	4.00	5.05	3.80	4.90	6.00	4.80	5.90	7.00
Dicalcium phosphate (18% P, 22% Ca)	1.86	1.86	1.86	1.86	1.86	1.86	1.86	1.86	1.86
Limestone flour (38.8% Ca)	0.52	0.52	0.52	0.52	0.52	0.52	0.52	0.52	0.52
Salt	0.30	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	0.25
DL-Methionine (98%)[3]	0.12	0.12	0.12	0.15	0.15	0.15	0.16	0.16	0.16
Calculated levels (%)									
Calcium	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
P (total)	0.71	0.71	0.71	0.71	0.71	0.71	0.71	0.71	0.71
Available P	0.47	0.47	0.47	0.47	0.47	0.47	0.47	0.47	0.47
Methionine	0.45	0.45	0.45	0.51	0.51	0.51	0.54	0.54	0.54
Methionine + cystine	0.80	0.80	0.80	0.88	0.88	0.88	0.94	0.94	0.94
Lysine	1.14	1.14	1.14	1.27	1.27	1.27	1.41	1.41	1.41
Crude fat	5.51	6.44	7.22	6.14	6.99	8.02	6.86	7.80	8.74
Analyzed levels (%)									
Crude fat	5.46	6.40	7.18	6.15	6.93	7.97	6.81	7.71	8.69
CP	20.97	20.95	20.97	22.88	22.96	22.95	24.94	24.98	24.97

[1]ME (kcal/kg)/CP (%).

[2]Provided the following per kilogram of diet: retinyl acetate, 3,500 IU; cholecalciferol, 1,000 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, 54.8 mg; copper, 6 mg; zinc, 55 mg; selenium, 0.3 mg.

[3]Degussa Corporation, Kennesaw, GA.

Table 2. Composition of experimental diets (%) fed 5 to 8 wk of age

Item	3,100/19[1]	3,150/19	3,200/19	3,100/21	3,150/21	3,200/21	3,100/23	3,150/23	3,200/23
Ingredients (%)									
Corn, yellow #2 (8% CP)	64.11	63.12	61.65	58.33	56.98	55.70	52.19	51.00	49.70
Soybean meal (48% CP)	25.64	25.64	26.00	30.60	30.90	31.10	35.80	35.90	36.10
Alfalfa meal	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Meat and bone meal (50% CP)	3.00	3.00	3.00	3.00	3.00	3.00	3.00	3.00	3.00
Poultry blended fat	3.20	4.19	5.30	4.00	5.05	6.13	4.90	6.00	7.10
Dicalcium phosphate (18% P, 22% Ca)	2.10	2.10	2.10	2.10	2.10	2.10	2.10	2.10	2.10
Limestone flour (38.8% Ca)	0.30	0.30	0.30	0.30	0.30	0.30	0.30	0.30	0.30
Salt	0.30	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	0.25
DL-Methionine (98%)[3]	0.10	0.10	0.10	0.12	0.12	0.12	0.15	0.15	0.15
Calculated levels (%)									
Calcium	0.95	0.95	0.95	0.95	0.95	0.95	0.95	0.95	0.95
P (total)	0.72	0.72	0.72	0.73	0.72	0.72	0.73	0.73	0.73
Available P	0.44	0.44	0.44	0.44	0.44	0.44	0.44	0.44	0.44
Methionine	0.42	0.42	0.42	0.45	0.45	0.45	0.51	0.51	0.51
Methionine + cystine	0.74	0.74	0.74	0.80	0.80	0.80	0.88	0.88	0.88
Lysine	1.01	1.01	1.01	1.14	1.14	1.14	1.27	1.27	1.27
Crude fat	5.90	6.75	7.70	6.45	7.34	8.27	7.08	8.02	8.98
Analyzed levels (%)									
Crude fat	5.86	6.68	7.67	6.42	7.30	8.19	6.99	7.97	8.91
CP	18.93	18.97	18.95	20.89	20.96	20.93	22.98	22.92	22.95

[1]ME (kcal/kg)/CP (%).

[2]Provided the following per kilogram of diet: retinyl acetate, 3,500 IU; cholecalciferol, 1,000 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, 54.8 mg; copper, 6 mg; zinc, 55 mg; selenium, 0.3 mg.

[3]Degussa Corporation, Kennesaw, GA.

to 8 WOA (Table 2). The TSAA:lysine for the 19, 21, and 23% CP diets was 73, 70, and 69%, respectively. Each dietary treatment was replicated 3 times and fed in a mash form. Both feed and water were provided ad libitum.

Growth Model

The Laird form of the Gompertz equation (Laird et al., 1965) was fit to the data. The following equation describes the Gompertz-Laird growth curve:

Table 3. Gompertz growth model coefficients[1] in a randombred population of the French guinea fowl broiler fed diets with varying concentrations of ME and CP

	Growth model coefficients					
Item	BW_0	L	K	t_i	W_i	W_A
ME (kcal/kg)						
3,050 (n = 18)	28.79[b]	1.09	0.26	5.76	774	2,032
3,100 (n = 18)	33.41[a]	1.06	0.25	5.68	770	2,037
3,150 (n = 18)	31.51[a]	1.08	0.25	5.67	765	2,090
Pooled SEM	0.94	0.02	0.00	0.08	17	35.3
CP (%)						
21 (n = 18)	33.56[a]	1.04[b]	0.25	5.73	738[a]	2,023
23 (n = 18)	30.70[b]	1.08[ab]	0.26	5.73	780[ab]	2,065
25 (n = 18)	29.64[b]	1.12[a]	0.26	5.65	789[b]	2,066
Pooled SEM	0.94	0.02	0.00	0.07	17.3	0.35
ME/CP						
3,050/21 (n = 6)	34.54[a]	0.99[c]	0.24[b]	5.94	750	2,082
3,050/23 (n = 6)	26.14[c]	1.14[b]	0.26[a]	5.64	799	1,984
3,050/25 (n = 6)	26.77[c]	1.13[b]	0.26[a]	5.72	768	2,040
3,100/21 (n = 6)	35.37[a]	1.02[bc]	0.25[ab]	5.66	743	1,997
3,100/23 (n = 6)	33.09[ab]	1.04[bc]	0.25[ab]	5.75	755	2,069
3,100/25 (n = 6)	31.58[ab]	1.22[a]	0.26[a]	5.63	819	2,044
3,150/21 (n = 6)	30.38[b]	1.10[b]	0.26[a]	5.61	721	1,997
3,150/23 (n = 6)	32.71[ab]	1.06[bc]	0.25[ab]	5.79	790	2,146
3,150/25 (n = 6)	31.26[ab]	1.10[b]	0.26[a]	5.59	781	2,127
ME × CP	NS	NS	NS	NS	NS	NS
Pooled SEM	1.58	0.03	0.01	0.13	28	61

[a–c]Means with different superscripts within a column of model terms differ significantly ($P < 0.05$).

[1]BW_0 = BW at hatch (g); L = instantaneous growth rate (per wk); K = the rate of exponential decay of the initial specific growth rate; t_i = time of maximum growth (wk); W_i = BW at time of inflection; W_A = asymptotic BW.

$$W_t = W_0 \exp[(L/K)(1 - \exp - Kt)],$$

where W_t = the weight of bird at time t; W_0 = the initial body (hatch) weight; L = the instantaneous growth rate (per wk); K = the rate of exponential decay of the initial specific growth rate, L, which measures the rate of decline in the growth rate. The parameters derived for the inflection point, t_i; the BW at the inflection point, W_i; BW at time of inflection; and the asymptotic body, W_A, are as follows:

$$t_i = (1/K)\log(L/K)$$

$$W_i = W_0 \exp((L/K)^{-1})$$

$$W_A = W_0 \exp(L/K).$$

The growth parameters for individual birds were generated. Differences in growth parameters between sexes were evaluated by *t*-test (SAS Institute, 2002). There was not significant difference between the sexes and as a result, the growth curve parameters were analyzed by combining the sexes, using PROC GLM (SAS Institute, 2002). The least squares means of the parameters among the various treatments were separated using the PDIFF and STDERR option.

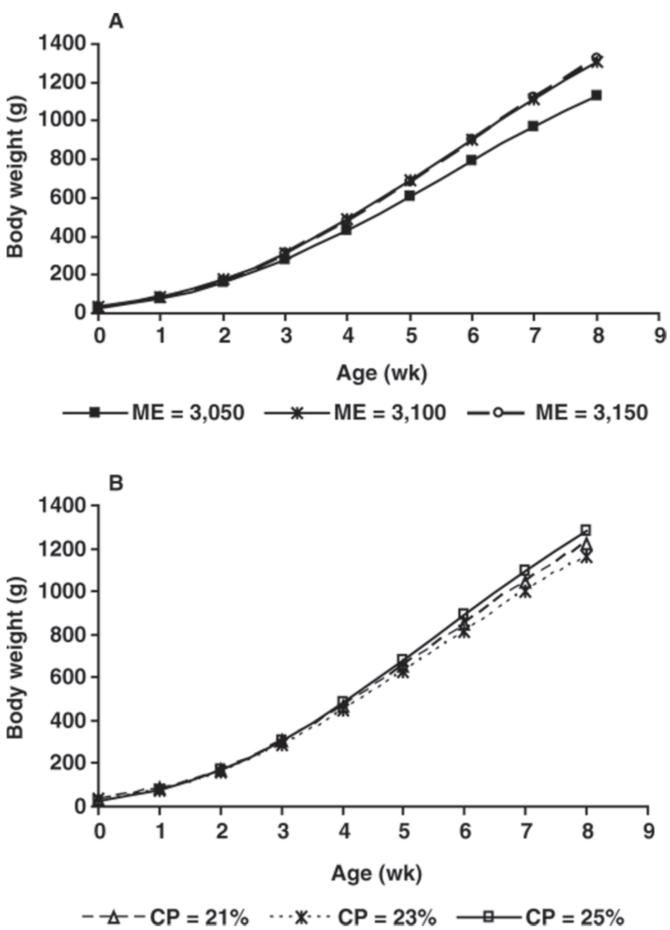

Figure 1. A. Effect of dietary ME concentrations (kcal/kg) on Gompertz-Laird model predicted growth curve of the French guinea fowl broiler. B. Effect of dietary CP concentrations on Gompertz-Laird model predicted growth pattern of the French guinea fowl broiler.

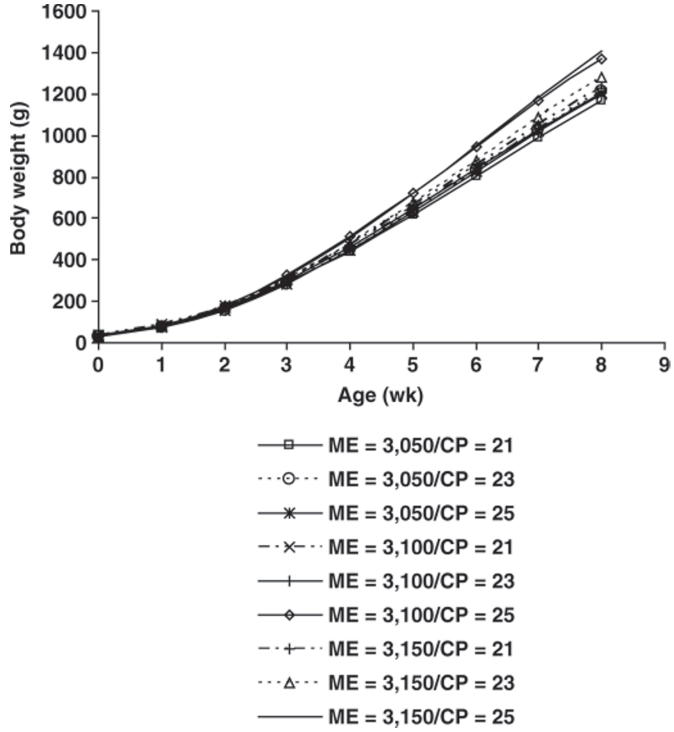

Figure 2. Effect of dietary ME and CP concentrations (kcal/kg and %, respectively) on Gompertz-Laird model predicted growth pattern of the French guinea fowl broiler.

RESULTS AND DISCUSSION

The means and SE of growth parameters predicted with the Gompertz-Laird growth model of the French guinea fowl broilers fed on various combinations of CP and ME are presented in Table 3. Earlier studies (Nahashon et al., 2006b) have shown the lack of sexual dimorphism for growth characteristics of the guinea fowl broiler. Likewise, in this study, differences between the sexes in growth curve parameters were not significant and as a result, the data for this report were combined for both sexes. Regardless of the level of dietary CP and ME, the SD of the predicted BW increased with age, a common phenomenon of time series data. The predicted initial BW (W_0) was significantly lower ($P < 0.05$) in birds fed diets containing 3,050 kcal of ME/kg when compared with those fed the 3,100 and 3,150 kcal of ME/kg diets. However, differences in instantaneous growth rate (L), rate of exponential decay (K), time at inflection point (t_i), BW at time at inflection point (W_i), and asymptotic BW (W_A) among dietary ME levels were not significant ($P > 0.05$).

Predicted initial BW, instantaneous growth rate, and BW at time at inflection point were significantly lower ($P < 0.05$) in French guinea broilers fed the 21% CP diet than those fed the 23 and 25% CP diets. Nahashon et al. (2005) have demonstrated that feed conversion, BW, and feed conversion ratios (**FCR**) were similar in

Table 4. Means and SEM for feed conversion ratios of a randombred population of the French guinea fowl broiler fed diets with varying concentrations of ME and CP

Item	Age (wk) 1 to 6	7 to 8	1 to 8
ME level (kcal/kg)	g of feed/g of weight gain		
3,050 (n = 18)	2.13[a]	4.99	2.43[a]
3,100 (n = 18)	2.04[ab]	5.46	2.31[b]
3,150 (n = 18)	1.93[b]	4.66	2.22[c]
Pooled SEM	0.03	0.49	0.04
CP level (%)			
21 (n = 18)	2.06	4.75	2.34
23 (n = 18)	2.04	4.81	2.31
25 (n = 18)	1.98	5.53	2.31
Pooled SEM	0.04	0.49	0.05
ME/CP			
3,050/21 (n = 6)	2.20[a]	4.66	2.47[a]
3,050/23 (n = 6)	2.17[a]	5.36	2.51[a]
3,050/25 (n = 6)	2.00[b]	4.94	2.30[b]
3,100/21 (n = 6)	2.03[b]	5.00	2.31[b]
3,100/23 (n = 6)	2.01[b]	4.55	2.25[b]
3,100/25 (n = 6)	2.07[b]	6.83	2.37[b]
3,150/21 (n = 6)	1.95[b]	4.60	2.23[b]
3,150/23 (n = 6)	1.94[b]	4.54	2.18[b]
3,150/25 (n = 6)	1.89[b]	4.83	2.27[b]
ME × CP	NS	NS	NS
Pooled SEM	0.05	0.89	0.05

[a–c]Means with different superscripts within a column of model terms differ significantly ($P < 0.05$).

French guinea broilers fed either 23 or 25% CP. Data from the current study and Nahashon et al. (2005) suggest that feeding 23% CP to French guinea broilers is adequate for optimal growth and feed efficiency.

The average time at inflection ranged from 5.59 to 5.94 wk (Table 3, Figures 1a and b and Figure 2). As previously demonstrated in chickens (Lopez et al., 2007) and guinea fowl (Nahashon et al., 2006a), regardless of dietary ME and CP concentrations, the growth curves in this study adopted a slow initial growth rate, which was followed by an accelerated growth phase and finally a slowdown in growth rate as these birds advanced in age. With the exception of birds fed the 3,100 kcal of ME/kg and 21% CP diet, the predicted initial BW of birds fed either the 3,100 or 3,150 kcal of ME/kg diet in combination with the 21, 23, or 25% CP diet were not different ($P > 0.05$), but they were significantly higher ($P < 0.05$) than those of birds fed the 3,050 kcal of ME/kg diet in combination with either 23 or 25% CP. The lowest instantaneous growth rate and rate of exponential decay were also observed in birds fed the 3,050 kcal of ME/kg and 21% CP diet. It has also been shown that carcass yield, feed conversion, and FCR were significantly higher in guinea fowl broilers fed either the 3,100 or 3,150 kcal of ME/kg diet than those fed the 3,050 kcal of ME/kg diet (Nahashon et al., 2005).

The FCR of birds fed the 3,150 kcal of ME/kg diet were significantly lower ($P < 0.05$) than those of birds fed the 3,050 kcal of ME/kg diet (Table 4). However, differences in FCR between birds on the 3,100 and 3,150 kcal of ME/kg diet were not significant. Differences in FCR among dietary CP levels were also not significant ($P > 0.05$). Among the dietary CP and ME combinations, FCR were significantly lower in birds fed the 3,050 kcal of ME/kg and 25% CP diet and 3,100 and 3,150 kcal of ME/kg with either 21, 23, or 25% CP when compared with those fed diets containing 3,050 kcal of ME/kg with either 21 or 23% CP. The improved performance of birds fed the 3,050 kcal of ME/kg and 25% CP diets may be attributed to the sufficiency of dietary amino acids, excess of which was used to compensate the energy deficiency (MacLeod, 1997). However, it should be pointed out that the differences in FCR were observed only between 1 and 6 wk, and hereafter, there were no significant differences among the protein and energy treatment combinations.

In the current study, the Gompertz-Laird estimates of instantaneous growth rate, time at inflection point, asymptotic BW, and FCR of the French guinea broilers fed diets containing 3,100 kcal of ME/kg and 23% CP were 1.04 kg/wk, 5.75 wk, 2,065 g/bird, and 2.22 g of feed per gram of weight gain, respectively. These means were not different ($P > 0.05$) from those of birds fed diets containing 3,100 kcal of ME/kg and 21% CP. Therefore, based on the Gompertz-Laird growth model estimates, feeding 21 and 23% CP and 3,100 kcal of ME/kg at hatch to 4 WOA and 19 and 21% CP with 3,150 kcal of ME/kg at 5 to 8 WOA can be recommended as adequate for growth for the French guinea fowl broilers.

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