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Modeling the growth curve of Japanese Quail under different nutritional environments

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Target Audience: Researchers & Animal producers

Abstract

Previous studies on Japanese quails have fitted non-linear models to growth data and assessed resultant parameters under a restricted nutritional environment. This study modeled the growth of Japanese quails under different nutritional environments, compared them in order to choose the best fitted model and investigated the statistical interaction between sex and diet using the best fitted model. Weekly body weight (BW) records were collected from 360 quails from hatch to 56 days. Bertalanffy, Gompertz and Logistic models were used for the study. Each model was fitted separately to BW using the NLIN procedure of SAS®. Parameters were estimated for each model and comparison was based on R^2, AIC and BIC. Across the diets, asymptotic weight (A) for Gompertz ranged from 147.0-162.7g, Bertalanffy, 152.0-176.7g and Logistic, 135.0-146.3g Growth rate (k) for Gompertz model ranged from 0.35-0.48, Bertalanffy, 0.29-0.37 and Logistic, 0.60-0.81. A for males of 22%-20%, 22%-22% and 26%-20% combinations were significantly ($P<0.05$) higher than those of other diet combinations. A for females of 26%- 20% were significantly ($P<0.05$) higher than those of other diet combinations. No significant difference ($P>0.05$) was observed in the k of both the male and female under all diets combinations. The study concluded that Logistic model (R^2=0.99634-0.99939; AIC=4.5392-57.9737; BIC=8.67-62.10) resulted in the best fit model.

Keywords: Nutritional environments, Non-linear models, body weight, growth rate and Japanese quails.

Description of Problem

Japanese quail (*Coturnix coturnix japonica)* has a small body size. Genetic evaluation of animals has been based on several traits depending on the species such as body weight, feed intake and longevity (1). Selection in poultry is traditionally based on body weight for a standard age, leading to a reduced age at slaughter. However, this kind of selection increases mature weight, which requires different management for breeders (2). Japanese quail is being used as a model type in poultry breeding experiments because of its short generation interval, high fertilization efficiency and simple equipment for its rearing (1). Growth models are of great importance for animal production in that they provide an opportunity for practical interpretations of growth and feed conversion (3). The most commonly used models to analyze growth of poultry are Von-Bertalanffy, Gompertz and Logistic models (4, 5, and 6). The parameters of growth models, and especially their biological meaning, are informative for breeders as they permit the inference and accurate prediction of relevant economic information with regard to the inflection point and maturity that are not accessible from simple analysis of growth traits such as weights at different key ages (birth, weaning and slaughtering) or daily gains. Hence, the need to model the growth of Japanese quails under different nutritional environment. Previous studies on Japanese quails have fitted non-linear regression models to growth data and assessed resultant parameters under a restricted nutritional environment. There are limited studies on quail for growth modeling under different nutritional environments, hence this study. Therefore, the objectives of the study were to model the growth curves of Japanese quails under different nutritional environments using three nonlinear growth models, to compare the models in order to establish the most appropriate model under different nutritional environments and investigate the statistical interaction between sex and diets in the growth model using the selected model.

Materials and Methods

The experiment was carried out at the Quails Unit of Obafemi Awolowo University, Teaching and Research Farm, Ile Ife, Nigeria located between Latitude 7° 30' - 7° 35' N and Longitude 4° 30' - 4° 35'E. Three hundred and sixty Japanese quails hatched from eggs collected from parents that were randomly mated were used for the study. After hatching they were randomly distributed to three dietary treatments each consisting of 40 birds in three replicates, they were tagged, weighed and brooded for 4 weeks. The dietary treatments contained three different levels of crude protein, 22, 24, and 26% each with 2,800 kcal/kg metabolizable energy. At the end of the 4th week, the birds under each dietary treatment were further randomly distributed to three new dietary treatments comprising 18, 20 and 22% crude protein each in three replicates consisting 40 birds each with 2,800 kcal/kg metabolizable energy. At the end of the 4th week, the birds under each dietary treatment were further randomly distributed to three new dietary treatments comprising 18, 20 and 22% crude protein each in three replicates consisting 40 birds each with 2,800 kcal/kg metabolizable energy. In all, there were nine (9) diets combination as follows: 22% starter and 18% finisher diet= T1; 22% starter and 20% finisher diet= T2; 22% starter and 22% finisher diet= T3; 24% starter and 18% finisher diet= T4; 24% starter and 20% finisher diet= T5; 24% starter and 22% finisher diet= T6; 26% starter and 18% finisher diet= T7; 26% starter and 20% finisher diet= T8; 26% starter and 22% finisher diet= T9. Individual body weight (BW) was obtained weekly from hatching to eight (8) weeks using a sensitive digital scale.

Statistical analysis

The nonlinear growth models, the Gompertz, the Bertalanffy and the Logistics were applied to the data using the PROC NLIN of SAS software. The parameters of these models were fitted based on the mathematical functions below:

Gompertz: $W_t = A*e^{(-B*e(-k*t))}$ (7)

Von-Bertalanffy: $W_t = A\,(1 - B*e^{-kt})^3$ (8)

Logistic: $W_t = A/(1 + B*e^{-k*t})$ (9)

W_t= Body weight of individual at age t (weeks), t = Age in weeks, A= Asymptotic weight (mature weight) of the animal; B= Constant of integration (the proportion of asymptotic weight), k= Growth rate/maturation rate (how fast animal approaches adult weight) and e= euler'number (~2.71828…).

Four statistics were used to determine the goodness of fit, that is, most appropriate model. These include coefficient of determination (R^2), Mean Square Error (MSE), Akaike Information Criterion (AIC) and Bayesian Information Criterion (BIC). The influence of different dietary crude protein levels and sex on the parameters of the selected model was also investigated using the procedure of nonlinear models (PROC NLIN) of SAS software.

Table 1 : Estimates of growth curve parameters under different crude protein combination

	Model Parameters								
	Asymptotic Weight (A)			Constant of Integration (B)			Growth Rate (k)		
Diets/ Models	Gomp	Bertfy	Logs	Gomp	Bertfy	Log	Gomp	Bertfy	Log
T1	147.0±7.71	152.0±13.37	135.0±2.46	3.14±2.32	0.69±0.07	11.98±1.32	0.44±0.05	0.33±0.06	0.77±0.04
T2	152.8±9.27	163.6±15.69	140.1±3.33	3.19±0.39	0.70±0.07	12.51±1.81	0.44±0.06	0.33±0.06	0.77±0.05
T3	154.1±11.13	167.0±19.03	139.4±4.21	3.26±0.43	0.71±0.07	13.29±2.33	0.42±0.06	0.31±0.07	0.76±0.06
T4	148.8±8.17	159.8±14.16	135.8±2.94	3.11±0.32	0.69±0.06	11.81±1.48	0.43±0.05	0.32±0.06	0.75±0.05
T5	151.2±9.62	162.9±16.55	137.6±3.38	3.20±0.38	0.70±0.07	12.64±1.81	0.43±0.06	0.32±0.06	0.76±0.05
T6	149.1±10.07	158.4±16.39	137.8±3.89	3.41±0.54	0.74±0.10	14.11±2.73	0.47±0.08	0.36±0.08	0.81±0.07
T7	162.7±17.31	176.7±24.40	146.3±11.00	2.56±0.29	0.61±0.05	7.69±1.87	0.35±0.07	0.29±0.06	0.60±0.10
T8	152.7±9.70	161.9±15.11	141.4±4.60	3.05±0.41	0.68±0.08	11.22±2.21	0.45±0.07	0.35±0.07	0.77±0.07
T9	150.5±8.72	158.4±13.43	140.8±4.18	3.06±0.42	0.69±0.08	11.15±2.17	0.48±0.07	0.37±0.07	0.80±0.07

Gomp=Gompertz model; Bertfy=Bertalanffy model; Logs=Logistic model; T1=22% starter and 18% finisher diet; T2=22% starter and 20% finisher diet; T3=22% starter and 22% finisher diet; T4=24% starter and 18% finisher diet; T5=24% starter and 20% finisher diet; T6=24% starter and 22% finisher diet; T7=26% starter and 18% finisher diet; T8=26% starter and 20% finisher diet; T9=26% starter and 22% finisher diet.

Results and Discussion

Table 1 shows the estimates of growth curve parameters under different crude proteins combination. The table shows that asymptotic weight (A) for Gompertz model ranged from 147.0-162.7g for all the treatments, Bertalanffy model ranged from 152.0-176.7g for all the treatments and Logistic model ranged from 135.0-146.3g for all the treatments. The constant of integration (B) of the growth functions for Gompertz ranged from 2.56-3.41 for all the treatments, Bertalanffy ranged from 0.61-0.71 for all the treatments, Logistic ranged from 7.69-14.11 for all the treatments. Growth rate (k) for Gompertz model ranged from 0.35-0.48, Bertalanffy model ranged from 0.29-0.37 and Logistic model ranged from 0.60-0.81.

Table 2: Goodness of fit criteria to select the most appropriate model

Goodness of Fit Criteria									
Diets/	R^2			AIC			BIC		
Models	Gomp	Bert	Logs	Gomp	Bert	Logs	Gopmp	Bert	Logs
T1	0.99628	0.95271	0.99891	54.8264	72.4558	4.5392	58.95	85.40	8.67
T2	0.99519	0.99162	0.99757	65.6220	79.8607	27.8250	71.60	93.14	33.80
T3	0.99448	0.99107	0.99741	72.0999	84.6285	41.8027	77.17	96.29	46.75
T4	0.99627	0.99317	0.99854	53.7872	69.7527	16.3404	58.85	83.02	21.41
T5	0.99529	0.99184	0.99819	65.9935	80.8396	26.8412	70.12	95.58	30.97
T6	0.99327	0.98891	0.99722	86.5716	107.5471	48.4703	88.55	109.73	50.64
T7	0.99141	0.99143	0.99939	78.3346	83.3262	37.8854	63.89	84.31	43.86
T8	0.99391	0.99072	0.99634	78.7904	89.7565	57.9737	82.92	100.10	62.10
T9	0.99388	0.99035	0.99654	79.1190	97.7380	55.8418	83.25	101.87	59.97

Gomp=Gompertz model; Bertfy=Bertalanffy model; Logs=Logistic model; T1=22% starter and 18% finisher diet; T2=22% starter and 20% finisher diet; T3=22% starter and 22% finisher diet; T4=24% starter and 18% finisher diet; T5=24% starter and 20% finisher diet; T6=24% starter and 22% finisher diet; T7=26% starter and 18% finisher diet; T8=26% starter and 20% finisher diet; T9=26% starter and 22% finisher diet.

Table 3: Estimates of asymptotic weight and growth rate ± standard error of logistic model, according to dietary crude protein levels and sex in Japanese quail

	Male		Female	
Growth parameter/ Diet	A	K	A	K
T1	125.3±1.99^{c}	0.78±0.04	143.9±4.00^{c}	0.76±0.06
T2	130.8±2.79^{a}	0.74±0.05	149.6±5.31^{b}	0.82±0.61
T3	134.3±3.74^{a}	0.74±0.06	143.6±4.98^{c}	0.78±0.07
T4	127.3±2.12^{b}	0.74±0.06	142.1±3.97^{c}	0.77±0.06
T5	129.9±2.82^{b}	0.77±0.05	146.3±4.60^{b}	0.76±0.06
T6	129.5±3.27^{b}	0.79±0.06	144.9±4.60^{c}	0.83±0.08
T7	128.6±2.66^{b}	0.76±0.05	148.5±4.69^{b}	0.78±0.07
T8	131.3±3.84^{a}	0.78±0.07	157.1±12.86^{a}	0.77±0.09
T9	128.7±3.31^{b}	0.77±0.06	149.8±5.66^{b}	0.82±0.10

^{a,b,c} Means within column with different superscripts are significantly (P<0.05) different.
A= Asymptotic weight, k= Growth rate; T3=22% starter and 22% finisher diet; T4=24% starter and 18% finisher diet; T5=24% starter and 20% finisher diet; T6=24% starter and 22% finisher diet; T7=26% starter and 18% finisher diet; T8=26% starter and 20% finisher diet; T9=26% starter and 22% finisher diet.

Table 2 shows the goodness of criteria to select the model that most appropriately fits the data on Japanese quail under different nutritional environments. The model that had the highest R^2 and lowest AIC and BIC was the model that best fits the data (10). The R^2 for Gompertz model ranged from 0.99141-0.99628, for Bertalanffy model ranged from 0.95271-0.99317 and Logistic model ranged from 0.99634-0.99939. Logistic model had the highest estimate for R^2. AIC for Gompertz model ranged from 53.7872-86.5716, Bertalanffy model ranged from 69.7527-107.5471 and Logistics model ranged from 4.5392-57.9737. BIC for Gompertz model ranged from 58.85-88.55, Bertalanffy model ranged from 83.02-109.73, and Logistics model ranged from 8.67-62.10.

Table 3 shows estimates of asymptotic body weight and growth rate of Logistic model, according to dietary crude protein levels and sex in Japanese quail. Asymptotic weight for males placed on T2, T3 and T8 were significantly ($P<0.05$) higher than the males under other diets. No significant difference was observed in the growth rates of the male birds under all diets combination. Asymptotic weight for females fed T8 was significantly ($P<0.05$) higher than that of the females fed other diets. No significant difference was also observed in the growth rates of the female birds under all diets combination. The results of this study agree with (11) who compared different models to describe the growth of Japanese quail fed 23% starter and 18% finisher diets and reported asymptotic weight of 153.111g for Gompertz and 151.227g for Logistic models. (6) reported 222.0g, 222.1g and 201.9g for Richards, Gompertz and Logistic models, respectively which are higher than those obtained in this study. This could be due to the fact that asymptotic weight is directly related to genotype and environmental effects; hence different quail genotypes managed in different environment would have different asymptotic weight (6). The results of this study disagree with (12) who compared Richards, Gompertz and Logistics for growth of Japanese quail and reported asymptotic weight of 200.3g for Logistic model under 26% starter and 22% finisher diet. The constant of integration (B) in this study for Gompertz and Logistic models were similar to (6) and (13) who reported 3.31 and 12.82; 3.80 and 16.24 for Gompertz and Logistic models, respectively. *B* for Bertalanffy in this study was close to that reported by (6) and (13) who reported 0.81-0.84 for chicken and 0.84 for Japanese quail, respectively. 'B' indicates the scaling parameter of the growth functions. This result agrees with (12) who reported growth rate of 0.3-0.4 and 0.6-0.7 for Gompertz and Logistic models, respectively but disagrees with (6) who reported 0.08, 0.14 and 0.05 for growth rate of Gompertz, Logistic and Bertalanffy models, respectively. On the basis of the R^2, AIC and BIC, Logistic model was the most appropriate model that best described the data on Japanese quail under different nutritional environments. The results of this study agree with (12) who reported that Logistic was the best model for describing the growth of Japanese quail when the data was truncated before maturity for males, but this result disagrees with (6) who reported R^2 of 0.99998, 0.99968 and 0.99918 for Gompertz, Bertalanffy and Logistic models; AIC of -2.010, 19.6830 and 24.37812 for Gompertz, Bertalanffy and Logistic models; BIC of -2.17221, 19.4670 and 24.21543 for Gompertz, Bertalanffy and Logistic models. (14) who compared Richards, Gompertz, Logistic, and a spline growth models in a study of growth in chickens reported high R^2 values for all four growth models. Reports on the significant interaction effect of different dietary crude protein and sex on the asymptotic weights (*A*) of Japanese quail are scarce in the literature.

Conclusion and Applications

1. The generally high R^2 for Gompertz, Bertalanffy and Logistic models observed in the present study indicates that the models were adequate in describing the growth pattern in Japanese quail under different nutritional environments.
2. However, based on the goodness of fit criteria; R^2, AIC and BIC values, the Logistic model best described the live weight data of Japanese quail under different nutritional environments. Asymptotic weight was influenced by different nutritional environments but growth rate was not.
3. The results of this study can help plan farm management strategies and decision-making regarding the culling of poor producers and selecting the highly productive animals just by considering their growth parameters.

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