EVALUATION OF FOUR CLASSICAL NON-LINEAR MODELS TO DESCRIBE THE GROWTH CURVE OF FUNAAB-ALPHA CHICKENS

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Abstract

The objective of this study was to evaluate four non-linear models (Gompertz, Logistic, Bertalanffy and Richard's) to describe the growth performance of FUNAAB-Alpha chickens (FAC). Three hundred (300) FAC chicks of both sexes were raised from day old till the 20th weeks of age. Body weight records were taken weekly and the NLIN procedure of SAS® was used to fit four non-linear growth functions. For all the models, parameter A (or asymptotic weight) ranged from 2050.8 to 3716.6g for the male and 1591.7 to 3330g for the female chicken respectively, while parameter B (constant of integration) ranged from 0.7541 to 15.441. Similarly, parameter K (maturity index) ranged from 0.0463 to 0.2002.The parameter A (asymptotic weight) was highest for Bertalanffy model while the Logistic model estimated the highest value of parameter B (the scaling parameter) and parameter K (maturity index). For all the models fitted, age at inflection point ranged between 13.30 and 17.63 weeks for male chickens and 14.23 and 19.94 weeks for female chickens, while the corresponding body weight at inflection point ranged between 754 and 1528 g and 586 and 1261 g for male and female chickens respectively. Using the Akaike Information Criterion (AIC) and Bayesian Information Criterion (BIC) as the goodness-of-fit criteria, the Bertalanffy and Gompertz growth models were adjudged as the best fit models for evaluating the growth of FAC.

Keywords: Non-linear models, Growth curve parameters, FUNAAB-Alpha chickens, Point of Inflection.

Introduction

Growth can be defined as body weight gain or weight gain of body parts with age. The process of growth, measured as body mass or body weight on a longitudinal time frame has often been summarized using mathematical equations fitted to growth curves and the objective of this curve fitting is to describe the course of body weight increase over time or age with mathematical parameters that are biologically interpretable (Aggrey, 2002). These parameters have biological interpretation in terms of growth process and their values, as well as their relationships with other parameters, provide a genetic basis for understanding growth process and to develop breeding strategies to alter or modify the trajectory of growth.

Many mathematical models have been applied for the study of growth performance in poultry research. These include Gompertz, Bertalanffy, Logistic and Richard's functions. These models are non-linear and they fitted curves that relate the age of the bird with its weight, characterized the different phases of growth of the bird, allowed the estimation of the animal's growth rate, the age at which the animal stops growing and when it reaches sexual maturity (Galeano-Vasco *et al*., 2014).

Funaab-alpha chickens is a new breed of chickens described as an improved, indigenous, tropically adapted and dual-purpose breed developed through crossbreeding and intensive selection over many generations for improved meat and egg production without sacrificing adaptation to the tropical environment (Adebambo, 2015). Knowledge about jts growth curve parameters will be useful in making effective management decisions relating to feeding, maximization of the growth period and evaluating the influence of environmental stress on growth. The objective of this study was therefore to compare Gompertz, Logistic, Bertalanffy and Richard's growth models for describing the growth trajectory of Funaab-alpha chickens.

Materials and Methods

Three hundred (300) day-old chicks of the FUNAAB-Alpha chickens (FAC) were obtained from the Hatchery Unit of the Federal University of Agriculture, Abeokuta. They were brooded for two weeks, wing tagged for identification and thereafter transferred to the deep litter pens. A sensitive digital scale was used to take the weekly body weight of the individual chicken from day old till the 20th week when the experiment was terminated. Four non-linear growth functions including Gompertz, Logistic, Bertalanffy and Richard's model were fitted using the NLIN procedure of SAS®(2003) using the following equations: $W_{t = A*exp\,(-B*\exp(-K*t))}$; $W_t = A\,(1 - B * e^{-K*t})^3$; $W_t = \frac{A}{1+B*exp(-k*t)}$ and $W_t = 1 + B * exp(-k*t)^{1/d}$ respectively.

A is asymptotic weight, B = scaling parameter, K= maturity index while d is shape parameters for Richard's model.

Results and Discussion

Table 1 shows the estimated growth model parameters for male and female FUNAAB-Alpha chickens (FAC) reared intensively under a deep litter system using Gompertz, Logistic, Bertalanffy and Richard's growth functions. For all the models, parameter (A) which is the asymptotic weight (maximum stationary weight) ranged from 2050.8-3716.6g for the male and 1591.7-3330g for the female chicken respectively while parameter (B), the scaling parameter (constant of integration) ranged from 0.7541-15.441. Likewise, parameter K, which is the maturity index ranged from 0.0463-0.2002. The Bertalanffy model estimated the highest asymptotic weight while the Logistic model estimated the least. The asymptotic weight estimated in this study by the Gompertz model is consistent with the findings of Zhao *et al.* (2015) and Al-Samarai (2015) on some improved indigenous chickens of China and meat-type chickens of Iraq respectively but higher than the values obtained by Aggrey (2002), Osei-Amponsah *et al.* (2014) and Ngeno *et al.* (2010) for Athens-Canadian chickens and local chickens in Ghana and Kenya respectively. The values of parameter A obtained for Logistic model is consistent with the values reported by Aggrey (2002) and Al-Samarai (2015) but lower than the values reported by Eleroglu *et al.*(2014) for some Turkish indigenous chickens. Parameter A obtained in this study for Richard's model in this study is consistent with the findings of Aggrey (2002) but higher than those reported by Rizzi *et al.*(2013) and Osei-Amponah *et al.*(2014) for chickens in Italy and Ghana respectively. The variations in the asymptotic weight of these chickens could be attributable to genetic differences, the system of management and the prevailing climatic conditions of the environment in which these chickens were raised as well as the various interactions which ultimately influence the growth trajectory.

Table 1: Estimated growth model parameters for FUNAAB-Alpha chickens

Male	Female

Model	A	B	K	D	A	B	K	D
Gompertz	3056.3	3.5503	0.0860	-	2521.0	3.5813	0.080	-
Logistic	2050.8	15.441	0.2002	-	1591.7	15.718	0.1964	-
Bertalanffy	3716.6	0.7541	0.0463	-	3330.6	0.7672	0.0417	-
Richards	3056.2	2.521	0.150	0.343	2520.9	2.852	0.147	0.352

Where A,B,K and D are the asymptotic weight, the scaling parameter, maturity index and the shape parameter for Richard's model respectively

Table 2 shows the body weight and age at inflection point for FAC as estimated by Gompertz, Logistic, Bertalanffy and Richard's models. For all the models fitted, age at inflection point for FAC ranged between 13.30 and 17.63 weeks for male chickens and 14.23-19.94 weeks for female chickens while the corresponding body weight at inflection point ranged between 754 and 1528 g and 586 and 1261 g for male and female chickens respectively. For both sexes, the Gompertz model estimated the highest body weight at inflection while the Logistic model estimated the least. Similarly, the Richard's model predicted the earliest age at inflection point while the Bertalanffy model estimated the highest age at inflection. For all the models, the males had higher body weight at inflection than females. However, the females had higher ages at inflection point than the corresponding males for all the models.

The goodness-of-fit tests for the Gompertz, Logistic, Bertalanffy and Richard's growth models are presented in Table 3. These included the Akaike Information Criterion (AIC) and Bayesian Information Criterion (BIC). The lower the values of AIC and BIC, the better fit is the data (Kaps and Lamberson, 2004). For both sexes, the Bertalanffy model had the lowest AIC and BIC and was adjudged the best fit model followed by Gompertz model, Richard's model and logistic model in that order. This is in agreement with the conclusion of Aworetan and Oseni (2018), Eleroglu *et al.*(2014), Ngeno *et al.*(2010) and Osei-Amponsah *et al.*(2014) that reported Bertalanffy as the best fit nonlinear models for some indigenous chickens in Nigeria, Turkey, Kenya and Ghana respectively while Darmani *et al.*(2003) selected the flexible Richard model as the best fit. The lesser fit of the Richard's model observed in this study may be due to the extra parameter in the model, for which it was penalized by the model selection criteria. It has also been reported as inadequate in providing good fit to data patterns and observation (Meng *et al.*, 1997). Aggrey (2002) suggested that the addition of the fourth parameter may represent an over-parametarization of the growth model.

Table 2: Body weight (g) and age (weeks) at inflection point

	Male		Female	
Model	**T_i (weeks)**	**W_i(g)**	**T_i (weeks)**	**W_i(g)**
Gompertz	14.73	1528	15.95	1261
Logistic	13.67	754	14.03	586
Bertalanffy	17.63	1101	19.94	987

Richards	13.30	1294	14.23	1070

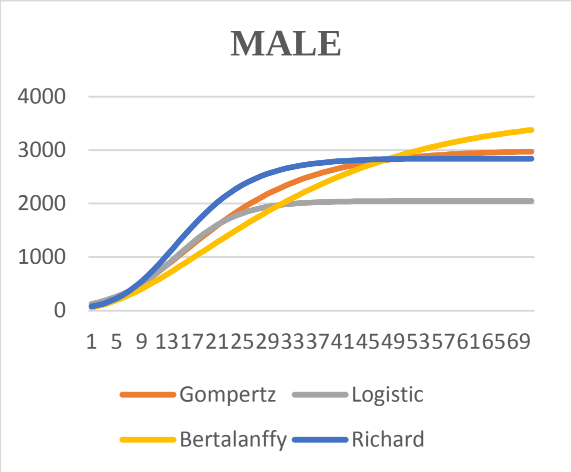
Where T_i is the age (weeks) and W_i is the body weight (g) at inflection point.

Table 3: Best fit model selection criteria using Goodness-of-Fit tests

	Male		**Female**	
Model	**AIC**	**BIC**	**AIC**	**BIC**
Gompertz	50.42	61.528	44.46	55.102
Logistic	53.23	64.488	47.10	58.342
Bertalanffy	**49.42**	**60.122**	**44.21**	**54.154**
Richards	50.42	61.778	46.76	57.813

Where AIC and BIC are Akaike Information Criterion and Bayesian Information Criterion and Bayesian Information Criterion respectively.

Graphical representations of the growth rate patterns of FAC are depicted in Figures 1 and 2. The growth curves showed the non-linear dependency of body weight on age. Body weight increased with age but at different rates which differed slightly from one model to the other.



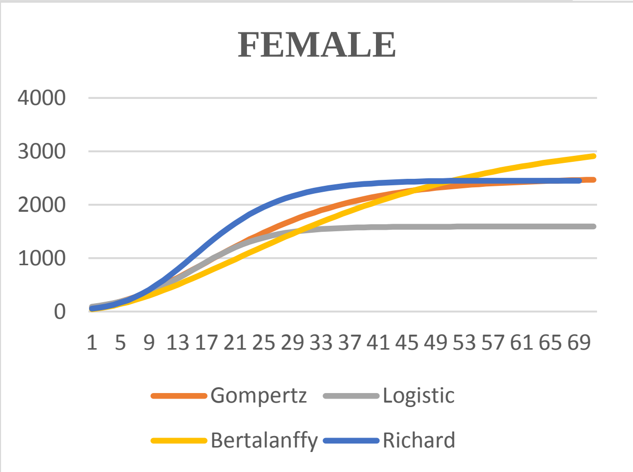


Fig 1 and 2: Growth curves for FAC predicted by Richards, Gompertz, Logistic and Bertalanffy growth models

Conclusion

The present study generated growth curves and growth parameters such as asymptotic weight (A), maturity index (K) and the constant of integration (B) for FAC. The predicted body weight from hatch till age at maturity were also generated. Among the non-linear models fitted, Bertalanffy and Gompertz models were found to be the best fit models.

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