Weight-Age Relationship in Yoruba and FUNAAB-Alpha Chickens using Non-linear Regression Models

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Abstract

This study was designed to evaluate the goodness of fit of six non-linear growth models; Logistics, Gompertz, Brody, Richard, Von bertalanffy and Mitscherlich in Yoruba and FUNAAB-Alpha chickens with the aim of providing information on their growth patterns for future genetic improvement. A total of 256 one-day-old chicks comprising 118 Yoruba Ecotype Chicken (YEC) and 138 FUNAAB Alpha Chicken (FAC) were tagged and fed ad libitum on starter (0 - 6 weeks) and grower (7-24 weeks) diets. Body weight of each bird was measured weekly. The selected nonlinear growth models were fitted to the individual body weights using the non-linear regression models and Levenberg-Marquardt iteration method of SPSS package version 22. The Akaike information criterion (AIC), coefficient of determination (R^2), and Bayesian information criterion (BIC) were adopted to determine the goodness of fit statistics. All the evaluated growth functions were successfully fitted to the observed growth data except the Richards function that failed to converge. Our findings showed that Gompertz and Von Bertalanffy model had the lowest BIC, AIC and highest R^2 values in YEC and FAC, respectively. Gompertz and Von Bertalanffy model best described live weight data of the Yoruba and FUNAAB-Alpha chickens, respectively. Thus, they could be used for prediction of bodyweight of these valuable stocks.

Key words: Indigenous chicken breeds, growth curve, nonlinear growth model, goodness of fit.

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Relation Poids-Âge chez les Poulets Yoruba et FUNAAB-Alpha en Utilisant des Modèles de Régression Non-linéaire

Résumé

Cette étude a été conçue pour évaluer la qualité d'ajustement de six modèles de croissance non linéaires : Logistique, Gompertz, Brody, Richard, Von Bertalanffy et Mitscherlich chez les poulets Yoruba et FUNAAB-Alpha dans le but de fournir des informations sur leurs modèles de croissance pour une amélioration génétique future. Un total de 256 poussins d'un jour comprenant 118 poulets écotypes Yoruba (YEC) et 138 poulets FUNAAB Alpha (FAC) ont été étiquetés et nourris ad libitum avec des régimes de démarrage (0 - 6 semaines) et de croissance (7-24 semaines). Le poids corporel de chaque oiseau a été mesuré chaque semaine. Les modèles de croissance non linéaires sélectionnés ont été ajustés aux poids corporels individuels en utilisant les modèles de régression non linéaire et la méthode d'itération de Levenberg-Marquardt du paquet SPSS version 22. Le critère d'information d'Akaike (AIC), le coefficient de détermination (R2) et le critère d'information bayésien (BIC) ont été adoptés pour déterminer les statistiques de qualité d'ajustement. Toutes les fonctions de croissance évaluées ont été ajustées avec succès aux données de croissance observées, sauf la fonction de Richards qui n'a pas réussi à converger. Nos résultats ont montré que le modèle de Gompertz et celui de Von Bertalanffy avaient les valeurs BIC et AIC les plus basses et les valeurs R2 les plus élevées chez les YEC et les FAC, respectivement. Les modèles de Gompertz et de Von Bertalanffy décrivent le mieux les données de poids *vif des poulets Yoruba et FUNAAB-Alpha, respectivement. Ainsi, ils pourraient être utilisés pour la prédiction du poids corporel de ces stocks précieux.*

Mots-clés : races de poulets indigènes, courbe de croissance, modèle de croissance non linéaire, qualité d'ajustement.

Introduction

Growth is a complex biological process that involves cell replication, tissues differentiation, matrix formation, cell death, and many other interrelated mechanisms (Raji *et al.,* 2013). The pattern of animal's growth can be described by set of mathematical functions called growth models. Appropriate growth models summarise the information provided on animals into concise interpretable biological parameters that can be used to describe animal growth over time (Menchaca *et al.,* 1996, Raji *et al.,* 2014, and Salako, 2014). The growth curve parameters can be used to estimate the expected weight of animal at a specific age, express the time-dependent non-linear variation of live weight and useful as selection criteria (Lopez *et al.,* 2000, Vázquez *et al.,* 2012 and Salako, 2014).

Previous studies have worked on growth modelling in chicken (Aggrey *et al.,* 2002; Roush *et al.,*2006; Atil *et al.,* 2007; Kucuk *et al.,* 2009 and Narinc *et al.,* 2010), turkey and ostriches (Ersoy *et al.,* 2006), Japanese quail (Ozkan *et al.,* 2004 and Raji *et al.,* 2014), sheep and goats (Raji, Gbangboche *et al.,* 2008, Ozdemir *et al.,* 2009). The commonest among the previous fitted non-linear growth curve functions include; Gompertz, Logistic, Von Bertalanffy, Brody, and Richard models. Aggrey *et al.,* (2002) assessed the appropriateness of the spline linear regression, Gompertz, logistic and Richards models in modeling the growth of random bred, unselected chicken population. The logistic model produced the best fit to the data compared to the spline regression model, Gompertz and Richards models Aggrey *et al.,* (2002). However, Teleken *et al.,* (2017) observed that Gompertz model fitted best to Athens-Canadian chickens' growth pattern. Further, estimation of the average growth curve for N'dama and White Fulani cattle breeds of Nigeria using Mitsherlich, Richard, and Gompertz functions revealed that Gompertz model fitted best in both breeds Salako, (2014). The suitability of Logistic and Gompertz growth models in estimating the growth parameters of Beetal and Angora goats have also been reported (Ozdemir *et al.,* 2009, Abdul-Waheed *et al.,* 2011). Although earlier authors have modelled growth of many chicken breeds using non-linear growth models, however, published reports on modelling of growth using non-linear growth models in Nigerian indigenous chickens is limited. In addition, the lack of consensus or universal model for all species or breeds of animals has proved that; models and shape of the growth curve are species/breed and environmental specific. Thus, finding an appropriate growth model which adequately described the weight-age relationship of indigenous/improved chicken breeds in Nigeria such as intended in this study is crucial.

Materials and Methods

The experiment was carried out with 256 one day-old chicks comprising 118 Yoruba ecotype and 138 FUNAAB-Alpha chicks. The chicks were wing-tagged at one-day-old, managed on a deep litter system and fed commercial starter (containing 23% crude protein and 11.1 MJ/ kg metabolizable energy) for 0-6 weeks and grower containing 18% crude protein and 10.48 MJ/ kg metabolizable energy for 7-24 weeks diets *ad-libitum* with unrestricted access to fresh clean water. The bodyweight of each chick was measured weekly. Five non-linear growth models: Gompertz, Brody, Logistic, Mitchelich and Von Bertallanffy were selected and fitted to the individual body weights for each age using the non-linear regression procedure and Levenberg-Marquardt iteration method of SPSS package version 22 (SPSS). Details of the non-linear models used in this study are presented in Table 1. The goodness of fit of the selected models were determined using coefficient of determination (R^2), Akaike's Information Criterion (AIC) and Bayesian Information Criterion (BIC).

$$\mathbf{R2 = 1 - (SSE/SST), AIC = n.\ln(SSE/n) + k\ln n, BIC = k\ln(n) - 2\ln(x)}$$

Where: SSE: Sum of Squared errors, SST: Total sum of Squares, R^2: coefficient of determination, n= number of observation, k= number of parameters, n: number of parameters, x= the data.

Table 1. Non-linear models used and their parameters

S/N	Name	Model
1	Mitscherlich	$Y = a - b * \exp(-k * age)$
2	Gompertz	$Y = a * \exp(-b * \exp(-k * age))$
3	Logistics	$Y = a/(1 + b * \exp(-k * age))$
4	Von bertalanffy	$Y = a * (1 - b * \exp(-k * age)) ** 3$
5	Brody	$Y = a * (1 - b * \exp(-k * age))$

Results

Logistic model predicted the highest initial bodyweight while the Mitscherlich model predicted the highest final bodyweight. The least and the closest to the observed mean bodyweight were also predicted by the logistic model for Yoruba chickens. Logistic model overestimated the initial body weight while, Mitscherlich model grossly underestimated it (Figure 4.0). All the four fitted models overestimated the initial bodyweight of FUNAAB-Alpha chickens with exception of Brody model which underestimated it (Figures 1-8). Brody model produced the highest predicted body weight (Table 2). The maturity rate value was similar for Gompertz and Von Bertalanffy while logistic model produced the highest maturing rate value in Yoruba chickens. Gompertz and Von Bertalanffy had the same and highest R^2 value (0.999) while the least R^2 value was observed in Mitscherlich model (Table 3). In FUNAAB-Alpha chickens, Logistic model produced the least mature body weight while the highest value of mature body weight was observed from Mitscherlich model. Conversely, the least integration parameter and maturity rate values were produced by Mitscherlich model (Table 3). Richard model (a four parameter model) failed to converge when fitted to the obtained growth data of Yoruba and FUNAAB-Alpha chickens. Gompertz model resulted in the highest R^2 and the lowest AIC and BIC values while Mitscherlich model had the least observed R^2 in Yoruba chickens. The least AIC and BIC values were obtained from Von Bertalanffy model in FUNAAB-Alpha chickens (Table 3).

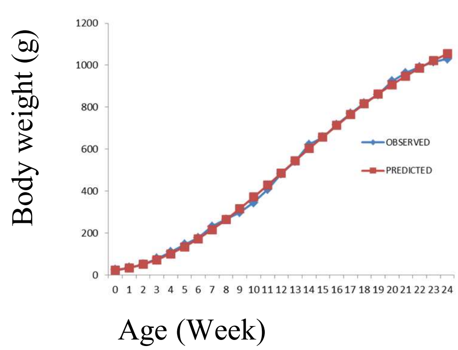

Figure 1.0 Logistic Growth curve for Yoruba Ecotype Chickens

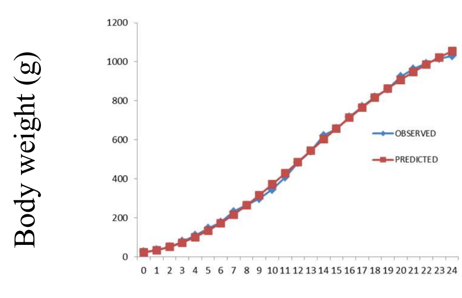

Figure 2.0 Gompertz Growth curve for Yoruba Ecotype Chickens

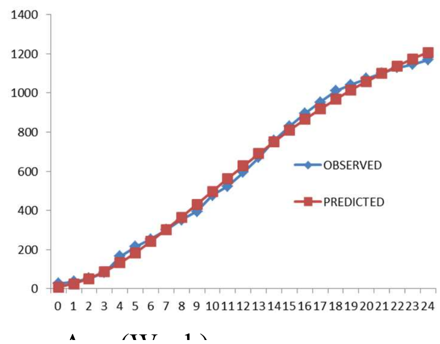

Figure 3.0 Von Bertallanffy Growth curve for Yoruba Ecotype Chickens

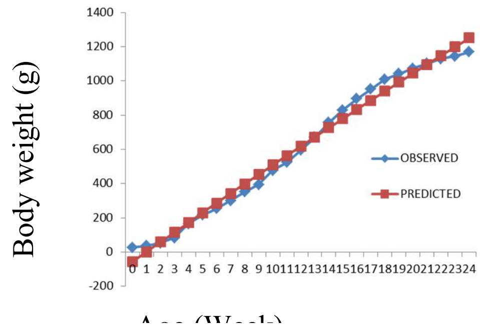

Figure 4.0 Mitchelich Growth curve for Yoruba Ecotype Chickens

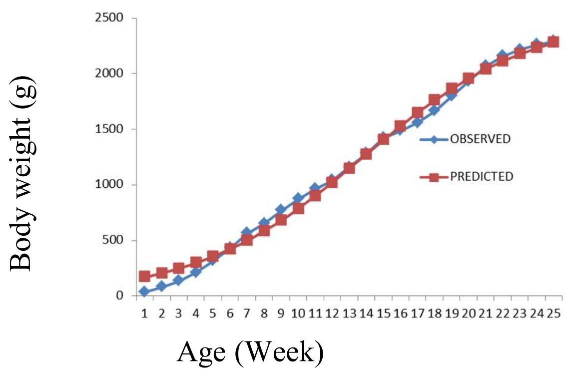

Figure 5.0 Logistic Growth curve for FUNAAB Alpha chickens

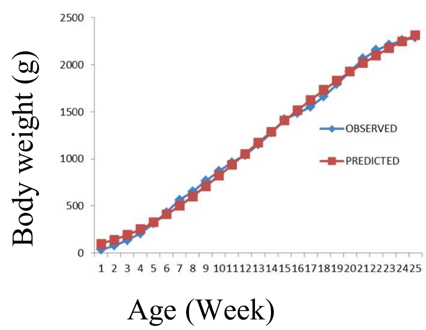

Figure 6.0 Gompertz Growth curve for FUNAAB Alpha chickens

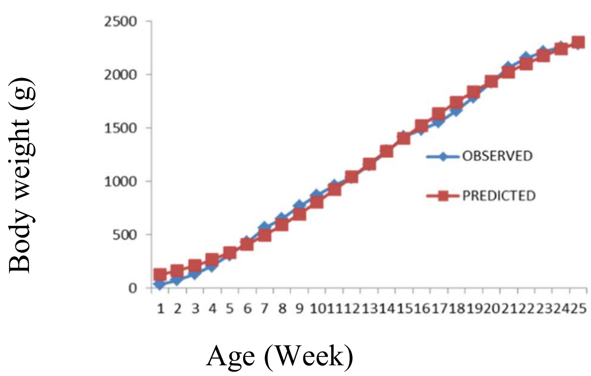

Figure 7.0 Von Bertalanffy Growth curve for FUNAAB Alpha chickens

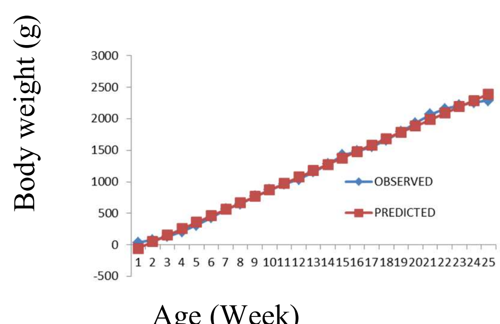

Figure 8.0 Brody Growth curve for FUNAAB Alpha chickens

Table 2.0. Estimated growth model parameters for Yoruba and FUNAAB-Alpha chickens

Breed	Model	A	B	K
Yoruba	Logistics	111.4.547	22.223	0.233
	Gompertz	1365.605	4.171	0.116
	Von Bertalanffy	500.906	4.161	0.126
	Mithchelich	1350708.147	135077.739	0.00
FUNAAB-Alpha	Logistics	2512.764	13.857	0.204
	Gompertz	3006.709	3.405	0.107
	Von Bertalanffy	2758	1.884	0.140
	Mithchelich	11480.859	1.00	0.001

A=asymptotic weight, B=constant of integration, K=maturity rate.

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

Breed	Model	R^2	AIC	BIC	SE
Yoruba	Logistics	0.998	62.71	60.890	15.932
	Gompertz	0.998	60.480	58.670	33.872
	Von Bertalanffy	0.999	85.360	83.550	12.461
	Mithchelich	0.987	85.390	85.580	0.007
FUNAAB-Alpha	Logistics	0.992	97.470	95.66	88.649
	Gompertz	0.996	88.150	86.350	122.748
	Von Bertalanffy	0.995	83.720	81.910	105.210
	Mithchelich	0.997	86.890	85.080	462668.370

R^2=coefficient of determination, AIC= Akaike' Information Criterion, BIC=Bayesian Information Criterion, SE=Standard Error.

Discussion

The patterns of growth over time and the expected weight of animal at a specific age can be estimated using growth models. In this study, the hatching weight of FUNAAB-Alpha was higher than those of Yoruba chickens (Table 2). The higher average hatching weight of FUNAAB-Alpha chicken above those of Yoruba chickens could be adduced to the successful genetic gain on FUNAAB-Alpha chicken improvement project. More so, higher body weight at day-old has been found to have positive association with superior mature weight in poultry. At day-old, the obtained average body weight of Yoruba chicken (24.45g - 26.76 g) was within the range (24.27 – 30.2 g) that was reported by Osaiyuwu *et al.,* (2009) in Yoruba and Fulani chickens. Similarly, FUNAAB-Alpha chickens had the higher mature bodyweight compared to the Yoruba chickens. However, the average body weight of FUNAAB-Alpha at week 20 was lower than 2115g that was reported by Olawumi and Fagbuaro, (2011) in commercial broilers at week 12.

The estimated asymptotic weight from the model comparison showed that Gompertz and Logistic models are better than those of Mitscherlich and Von Bertalanffy in Yoruba chicken. This is in agreement with the reports of Kucuk and Eyduran (2009) and Narinc *et al.,* (2010) that ranked Gompertz ahead of Logistic models in terms of asymptotic weight. More so, the asymptotic weight obtained in this study was consistent with the range 1591.7 ± 118.4 - 3716.6 ± 951.3 reported by Bashiru et al., 2019 in FUNAAB-Alpha chickens. Gompertz and Von Bertalanffy had the same rate of maturing (k) value while the highest maturing rate 'k' value was found in Logistic model. Also, Gompertz and Bertalanffy were reported as best suitable model for Fulani chickens in Nigeria

Sanusi and Oseni (2019). The coefficient of determination (R^2) was generally high for all the four fitted models (0.987 – 0.999). This indicates that ≥98% of the variability in the body weight of Yoruba ecotype chickens was explained by the models. Thus, all the fitted models adequately described the observed Yoruba chickens growth data. This is similar with the findings of Narinc *et al.,* (2010) and Sanusi and Oseni (2019) in chickens. Comparatively, the Mitscherlich model had the poorest fit (highest BIC and AIC values and lowest R^2 value) while the Gompertz model fitted best (lowest BIC and AIC values and highest R^2). Similarly, Aggrey (2002) and Hruby *et al.,* (1996) reported that Gompertz gave the best description of broiler chicken growth compared to the Logistic and linear models. Teleken *et al.,* (2017) and Selvaggi *et al.,* (2015) reaffirmed that Gompertz model fitted live weight data of Italian chicken and Athens-Canadian chickens better than the Logistic and Richards growth curve models (having the highest R^2 and lowest AIC and BIC values). However, Ersoy *et al.,* (2006) ranked Richard ahead of Gompertz model as the best descriptor of chicken, turkey and ostrich growth pattern. The contrasting submissions of the earlier authors could be adduced to factors such as genetic/breed differences of the studied chickens and or other environmental factors such as the feeding regime.

In FUNAAB-Alpha chickens, Logistic model produced the least asymptotic weight 'a' value while the highest value of asymptotic weight 'a' was observed from Mitscherlich model. Conversely, the least rate of maturity value 'k' and parameter 'B' value were produced by Mitscherlich model (Table 3). The smaller estimation of 'k' value indicated longer periods of growth and higher mature weights (24-25). The asymptotic weights estimated in this study were closer to the values reported by (16) and (23) in Italian and Athens-Canadian chicken breeds, respectively. The observed R^2 values in FUNAAB-Alpha (0.992 - 0.997) fall within the reported R^2 ranges in an unselected quail population, nondescript Italian chicken and broiler chickens (20, 27-28, respectively). However, the Von Bertalanffy model best described the live weight data of FUNAAB-Alpha (highest R^2 value and lowest BIC and AIC values). Earlier; Bertalanffy have consistently been reported as the best fit model for some local chickens in Kenya, Turkey, Ghana, and Italy (23, 29-30). The lack of consensus on a single growth model as universal for all chicken breeds such as observed in this study could be adduced to genetic/ breed differences, population structure, feeding and or other environmental conditions.

Conclusion

Our results showed that Yoruba and FUNAAB-Alpha chicken's growth can best be described using Gompertz and Von Bertalanffy model, respectively.

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