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Comparative Evaluation of Growth Functions in Three Broiler Strains of Nigerian Chickens

Adenaike, A. S.[1]*, Akpan, U.[1], Udoh, J. E.[2], Wheto, M.[1], Durosaro, S. O.[1], Sanda, A. J.[1] and Ikeobi, C. O. N.[1]

[1]*Department of Animal Breeding and Genetics, Federal University of Agriculture Abeokuta, Ogun State, Nigeria*
[2]*University of Uyo, Uyo, Akwa-Ibom State, Nigeria*

ABSTRACT

This study was conducted to compare five growth functions (Brody [B), Logistic [L], Gompertz [G], Von Bertalanffy [VB] and Richards [R]) in describing the body weight changes across age in three broiler ecotypes. Each chick was wing-tagged at day old and weighed on a weekly basis up to 10 weeks of age. Aforementioned non-linear growth models were fitted to appraise age-body weight relationship using procedure NLIN of the S.A.S (Version 9.1). G, L and VB functions converged with a low number of iterations ranging from 8 to 33 in Marshal, 7 to 10 in Naked Neck and 5 to 9 in Normal Feathered chickens. VB had the highest number of iterations (33, 10 and 9) for Marshal, Naked Neck and Normal Feathered chickens, respectively. The G, VB and L models fitted the growth curves of all the chicken ecotypes very well, and the fitting degrees R^2 were all above 99.89. Based on all the criteria used for comparing these models in the three ecotypes, it can be established that the L function gave the best fit for the age-body relationship although G and VB functions were equally good in predicting the growth curves of the chickens. B and R functions were not good in fitting chicken growth data in this study with respect to parameter estimates, convergence criteria and p values.

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E-mail addresses:
adenaike20094help@yahoo.com (Adenaike, A. S.),
ubong.akpan2012@gmail.com (Akpan, U.),
jessieezekiel@yahoo.com (Udoh, J. E.),
whepet@yahoo.com (Wheto, M.),
durosaroso@funaab.edu.ng (Durosaro, S. O.),
sandaaj@funaab.edu.ng (Sanda, A. J.),
ikeobic@yahoo.co.uk (Ikeobi, C. O. N.)
* Corresponding author

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INTRODUCTION

Broilers are strains of chickens used for the purpose of producing a huge quantity of chicken meat in a short period. Broiler chickens are raised from six to 10 weeks

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in poultry farms in Nigeria. Capability to raise big broilers in a short period requires only a small amount of money, thereby creating cheap and nutritious meat for the populace. The growth process of these broiler chickens with respect to parameters having a genetic interpretation is explained using growth curves. These parameters allow biological growth processes to be explained. Selection for growth rate can modify these parameters (Blasco et al., 2003). Selection on this growth curve could aid genetic gain on body weight of broiler chickens. Growth curve parameters describe the age-body weight relationship in chickens, and these traits are heritable (Mignon-Grasteau et al., 1999).

The contributions of research to the poultry industry in past years have led to the production of bigger chickens today. Gueye (1998) reported that traditional chickens had contributed a substantial amount to meat production (25-70%) and eggs (12-36%), and accounted for approximately 80% of the total chicken population in sub-Saharan Africa. Some Nigerian indigenous chickens have been genetically selected over time and they are about double the size of the strains (strains not subjected to genetic selection) that are scavengers in rural areas. Many reports are available on growth curves in livestock such as cattle (Brown et al., 1976; Kratochvilova et al., 2002), rabbit (Blasco et al., 2003), turkey (Seng & Küraz, 2005), chicken (Mignon-Grasteau et al., 2000; Norris et al., 2007). However, there is little information available on the evaluation and analysis of growth curves of Nigerian locally adapted broiler chickens. Growth curves, like other traits that are necessary for development, are important for the understanding and design of breeding plans because they change in response to selection (Gwaze et al., 2002).

Non-linear models have been used broadly to describe variations in body weight with age, so the genetic potential of chickens for growth can be assessed. A number of non-linear models have been compared and used to evaluate the growth curves of different chicken breeds (Stephan et al., 1987; Knizetova et al., 1991, 1995; Roush & Branton, 2005). These models include Brody (Brody, 1945), Gompertz (Winsor, 1932), Von Bertalanffy (Von Bertalanffy, 1957), Logistic (Nelder, 1961) and Richards (Richards, 1959). An appropriate growth function, therefore, summarises this information provided by observation on chickens and mathematically expresses its life time growth course (Kratochvilova et al., 2002). The aim of this study was to estimate growth curve parameters using different growth models to determine the age-body weight relationships of three chicken ecotypes.

MATERIALS AND METHOD

The research was carried out at the Poultry Breeding Unit of the Federal University of Agriculture, Abeokuta, (FUNAAB) located in latitude 7˚10 N in Odeda Local Government Area, Ogun State, South-Western Nigeria. The ambient temperature during the period ranged from 26.9˚C in June to 27.1˚C in December with an average relative humidity of 80%, while the vegetative site was an inter-phase between the tropical rainforest and the derived savannah (AGROMET, FUNAAB, 2015).

Experimental Animals and Their Management

One hundred and twenty broilers (40 per ecotype) from a commercial strain (Marshal) and two Nigerian indigenous chicken ecotypes (Normal-Feathered and Naked Neck) generated from a hatchery in Abeokuta were used for the study. The chicks were raised for 10 weeks and fed *ad libitum* on a broiler starter diet from day-old to 4 weeks old and a broiler finisher diet for the remaining weeks. All the necessary vaccines for broiler chicks were administered at the appropriate ages. The chickens were wing-banded at 1 day of age and the body weight of the birds was recorded on a weekly basis up to 10 weeks of age. Widely used non-linear growth models, Brody, Gompertz, Logistic, Von Bertalanffy and Richards, were fit to estimate the mean age-body weight relationship using procedures (NLIN) of the S.A.S (Version 9.1). To examine the accuracy of the model used, the fitting criteria were coefficient of determination (R^2) and standard error of prediction. Coefficient of determination (R^2) accounts for amount of the total variation due to the explanatory variable. The models were given as follows:

Gompertz: $y_t = Ae^{-b\exp(-kt)} + \varepsilon_t$

Logistic: $y_t = A/(1 + e^{-kt}) + \varepsilon_t$

Brody: $y_t = A(1 - be^{-kt}) + \varepsilon_t$

Richards: $y_t = A(1 - be^{-kt})^m + \varepsilon_t$

Von Bertalanffy: $y_t = A(1 - be^{-kt})^3 + \varepsilon_t$

where y_t represented the weight of the animal at a given age (t); parameter A was the asymptotic weight, if $t \rightarrow \infty$; when the adult weight of the animal was not reached, this reflected in an estimate of the weight of the last weighing; b was a constant without biological interpretation, but it was important to model the sigmoidal format of the growth curve from birth (t=0) up to the adult age of the animal ($t \rightarrow \infty$); K was the maturity index, which expressed the ratio of the maximum growth rate in relation to the adult size, where lower k values indicated delayed maturity and higher k values indicated accelerated maturity; M was the parameter that shaped the curve; e was the natural base logarithm; the L parameter had no biological meaning, but together with K constituted b, which had the function of modelling the sigmoidal curve; and ε represented the residue error associated with each weighing.

RESULTS AND DISCUSSION

The fitting of the Brody, Gompertz, Logistic, Von Bertalanffy and Richards functions offered no computational difficulty for any of the three chicken ecotypes considered in terms of computational time and convergence as these three curves converged to solutions at a short time interval for the three chicken ecotypes. In the Brody and Richards curves, convergence solutions were not attained for all the chicken ecotypes. The Gompertz, Logistic and Von Bertalanffy functions achieved convergence with a low number of iterations ranging from 8 to 33 in Marshal, 7 to 10 in Naked Neck and 5 to 9 in Normal Feathered chickens. The Von Bertalanffy function had the highest number of iterations (33, 10 and 9) for Marshal, Naked Neck and Normal Feathered chickens, respectively. This lack of convergence in all ecotypes for the Brody and Richards functions indicated lack of usefulness of the functions (Lopez de Torre et al., 1992) in this study because the models showed inadequacy in fitting all the growth data reasonably.

The means and their standard errors for the parameters estimated were used as a basis for the comparison of the models in all the chicken ecotypes. The means and their standard errors for the parameters estimated for the growth constant of each function in Marshal chickens are shown in Table 1. Average mature weight (A) values from the Logistic function was the closest to the observed values, followed by the Von Bertalanffy then the Gompertz functions. The Brody function overestimated A, while the Richards function underestimated A. The value of *b* for the Marshal ecotype ranged from -1.0377 to 29.7607. The highest value of *k* was observed in the Gompertz function (0.3930). The larger estimates of A were generally more associated with smaller estimates of *k* in the Brody function than were found in other models. The results of this study tend to corroborate the views and observations of Brown et al. (1976) that a non-positive correlation between *k* and A implies that early maturing animals tend to grow to a lower mature weight. The Gompertz, Logistic and Von Bertalanffy functions were superior to the Richards and Brody functions in terms of the values of the coefficient of determination (R^2), standard errors of the estimated parameters, convergence criteria and *p* values.

Table 1
Means and standard errors of the parameter estimates and coefficient of determination of five growth models fit for Marshall chickens

Model	Parameters	Mean	SE	R^2 (%)	Convergence	*p* value
Brody	A	10927.3	710274.0	66.91	Not converged	Not significant (0.05)
	b	0.997	0.148			
	k	0.006	0.407			
Gompertz	A	4656.4	546.2	99.90	Converged	Significant (0.0001)
	b	4.657	0.0673			
	k	0.121	0.0007			
Logistic	A	1823.4	173.4	99.96	Converged	Significant (0.0001)
	b	29.7607	2.3952			
	k	0.3930	0.026			
Von Bertalanffy	A	3566.53	1966.78	99.99	converged	Significant (0.0001)
	b	1.8984	0.0157			
	k	0.277	0.0068			
Richards	A	1.2681	30434.5	52.65	Not converged	Significant (0.05)
	b	-1.0377	188552			
	k	-2.5822	341868			
	m	0.1283	16987.9			

SE=standard error, R^2= coefficient of determination, A=Asymptotic weight, *b*=integration constant, *k*=maturity rate, *m*=point of inflection

Table 2 shows the growth curve parameters and their R^2 values for Naked Neck chickens. All the models had considerably high values of R^2 while the Von Bertalanffy function had the highest values for R^2 (99.98), followed by the Gompertz and Logistic functions that shared the same value of R^2 (99.97). The high R^2 for the models were close to unity and indicated a good overall measure of fitness (Lopez et al., 2000). Also, the Gompertz, Logistic and Von Bertalanffy functions were superior to the Richards and Brody functions in terms of the values of coefficient of determination, standard errors of the estimated parameters, convergence criteria and *p* values. When comparing the Gompertz, Von Bertalanffy and Logistic models whose *p* values were highly significant and converged within a short time, the Logistic function was preferable in terms of closeness of average mature weight and its standard error to the observed values.

Table 2
Means and standard errors of the parameter estimates and coefficient of determination of five growth models fit for Naked Neck chickens

Model	Parameters	Mean	SE	R^2 (%)	Convergence	*p* value
Brody	A	8848.7	338863	85.15	Not converged	Not significant (0.05)
	b	0.9975	0.0909			
	k	0.0053	0.2097			
Gompertz	A	1206.00	128.6	99.97	Converged	Significant (0.0001)
	b	3.4796	0.0894			
	k	0.1712	0.0162			
Logistic	A	810.6	67.2784	99.97	Converged	Significant (0.0001)
	b	15.4213	1.9833			
	k	0.4056	0.0396			
Von Bertalanffy	A	1885.9	363.9	99.98	Converged	Significant (0.0001)
	b	0.7428	0.0106			
	k	0.0905	0.0139			
Richards	A	361.6	119261	70.36	Not converged	Significant (0.05)
	b	0.0379	3669.5			
	k	0.055	162.6			
	m	7.6693	749304			

SE=standard error, R^2=coefficient of determination, A=Asymptotic weight, b=integration constant, k=maturity rate, m=point of inflection

Table 3 shows the growth function parameters and their R^2 values for Normal Feathered chickens. All the models had considerably high values of R^2 while the Gompertz model had the highest values for R^2 (99.99), followed by the Von Bertalanffy model (99.97). The Gompertz, Von Bertalanffy and Logistic models fit the growth curves of the three chicken ecotypes very well, and the fitting degree values, R^2, were all above 99.89. This is in consonance with reports of Eleroglu et al. (2014) and Zhenhua et al. (2015), who observed similar reports with the Gompertz, Von Bertalanffy and Logistic models in slow-growing chicken genotypes and indigenous chicken breeds in China, respectively.

Table 3
Means and standard errors of the parameter estimates and coefficient of determination of five growth models fit for Normal Feathered chickens

Model	Parameters	Means	SE	R^2 (%)	Convergence	*p* value
Brody	A	7791.6	159320	92.38	Not converged	Not significant (0.05)
	b	0.9986	0.0241			
	k	0.0064	0.1361			
Gompertz	A	1232.8	95.4757	99.99	Converged	Significant (0.0001)
	b	3.7746	0.064			
	k	0.1685	0.0108			
Logistic	A	785.2	51.7345	99.95	Converged	Significant (0.0001)
	b	18.8210	1.9498			
	k	0.4172	0.0307			
Von Bertalanffy	A	2159.1	500.5	99.97	Converged	Significant (0.0001)
	b	0.7781	0.0103			
	k	0.0821	0.0139			
Richards	A	841.0	1722.7	81.65	Not converged	Significant (0.05)
	b	-0.0194	21.514			
	k	0.2627	1.8705			
	m	-121.7	133491			

SE=standard error, R^2=coefficient of determination, A=Asymptotic weight, b=integration constant, k=maturity rate, m=point of inflection

General differences in fit of the five models in all the ecotypes are illustrated in Figures 1, 2 and 3. Straight lines observed in Figures 1 and 2 indicated that the Richards model projected the growth data of Naked Neck and Marshall chickens poorly but did better in projecting the growth data of Normal Feathered chickens. The fit of curves obtained from using the Richards and Brody models varied from those of other models over the different time periods. This is an important consideration from the stand point of choosing an appropriate model. Models that yield differences between predicted and actual weight at short intervals are preferred over models that yield deviations at longer intervals.

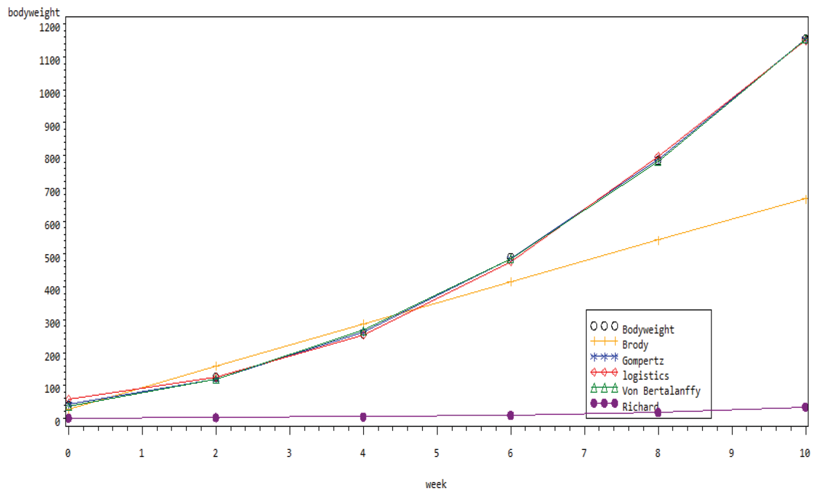

Figure 1. Estimates of growth, in g, of Marshall chicken ecotype according to age, in weeks, obtained by the models Brody, Gompertz, Logistic, Von Bertalanffy and Richards and observed mean weight

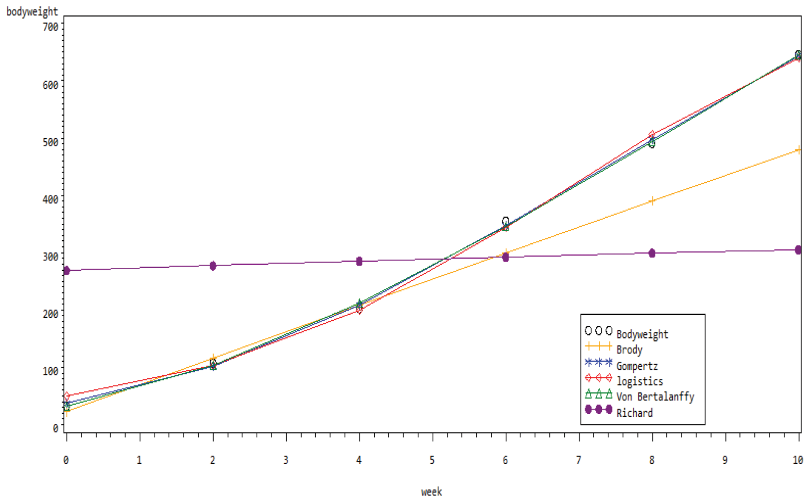

Figure 2. Estimates of growth, in g, of Naked Neck chicken ecotype according to age, in weeks, obtained by the models Brody, Gompertz, Logistic, Von Bertalanffy and Richards and observed mean weight

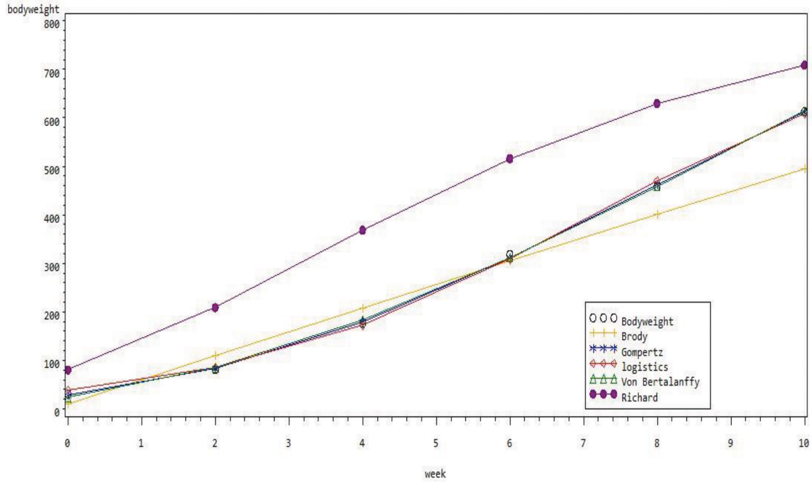

Figure 3. Estimates of growth, in g, of Normal Feathered chicken ecotype according to age, in weeks, obtained by the models Brody, Gompertz, Logistic, Von Bertalanffy and Richards and observed mean weight

CONCLUSION

Based on all the criteria used for comparing these models in the three genetic groups (Marshal, Naked Neck and Normal Feathered chickens), it could be established that the Logistic function used in this study gave the best fit for the data analysed although the Gompertz and Von Bertalanffy functions were equally good in predicting the growth curves of the chickens. The Brody and Richards functions were not suitable for fitting chicken growth data in this study with respect to parameter estimates, convergence criteria and *p* values. Also, based on growth curve parameters, the Marshal genetic group had a better rate of maturing and greater mature weight, followed by Naked Neck and then Normal Feathered chickens. Hence, Naked Neck chickens are recommended over Normal Feathered ecotypes for broiler production in breeding programmes based on the growth curve parameters for the five models considered in this study.

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