Nigerian Fulani ecotype chickens - II – Estimation of growth curve parameters

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Abstract

In the study, growth curves of Nigerian Fulani ecotype chickens (NFEC) were modelled under two production systems with four non-linear growth functions with a view to establishing growth descriptors for NFEC. Two hundred, day-old chicks of NFEC were obtained from an established population of NFEC. The chickens were separated randomly to intensive and pastured poultry production systems at 12 weeks of age. Data on body weight were taken weekly over a period of 20 weeks. Four non-linear growth functions including Gompertz, Logistic, Bertalanffy and Richard's models were fitted using the NLIN procedure of SAS® while the best fit model was selected using the goodness-of-fit tests. For all the models, parameter (A), the asymptotic weight, ranged between 1800g and 2417g for male and 1208g and 1550g for female chickens respectively. Parameter (B), the scaling parameter ranged from 0.77 and 19.79. Parameter K, which is the maturity index, ranged between 0.16 and 3.97 for both sexes. The R^2 values ranged between 0.9689 and 0.9987 for all the models fitted. Gompertz and Bertalanffy models emerged as the best fit functions. Age and body weight at inflection of NFEC were also predicted by the study. Growth curve parameters of NFEC in the pastured poultry system were not significantly different from those in the intensive system. The growth curve parameters estimated indicates that NFEC growth performance can be improved through effective breeding strategies and improved management practices.

Keywords: Growth curves; modelling; descriptors; parameters

Introduction

Rearing of indigenous chickens makes a substantial contribution to household food security throughout the developing world. This practice helps to diversify household income and provides quality food, protein, fertilizer, among other benefits to millions of rural households (Dolberg, 2003; IFAD, 2011). The rearing of indigenous chickens is an integral part of the smallholder farming systems in developing countries. The special adaptation of local chickens to environmental stresses and poor husbandry practices has made them the stocks of choice for smallholder production systems (Gondwe, 2001; Sonaiya and Swan, 2004; INFPID/FAO/IFAD, 2012). Nigeria is endowed with locally adapted chickens that are found in different ecological zones where they contribute significantly to the livelihoods of low-income families in urban, peri-urban and rural settlements (Ajayi, 2010). These chickens have been reported to possess untapped intrinsic growth potentials (Fayeye *et al.,* 2005). The Fulani ecotype chicken (a popular indigenous chicken in Nigeria) has been described as a potential meat type chicken because of its broiler-like body conformation, with mature body weight ranging between 0.9 Kg and 1.5 Kg; and 1.5 to 2.0 Kg for hens and cocks respectively (Fayeye *et al.,* 2005; Sola-Ojo and Ayorinde, 2009). However, there is limited information on the growth curve parameters of this ecotype chicken under different production systems. Many reports on the growth performance evaluation of

NFEC were based on a single production system, usually intensive system (e.g. Adedokun and Sonaiya, 2001; Fayeye *et al.,* 2005; Sola-Ojo *et al.,* 2011; Jesuyon and Salako, 2013).

Growth, a fundamental characteristic of living organisms, defined as the increase in body size per unit time, is a complex trait of economic importance in any poultry operation (Aggrey, 2002; Narinc, *et al.,* 2010; Selvaggi *et al.,*2015). Growth, being a continuous and dynamic process requiring integration of numerous mechanisms, is influenced by ecological, genetic and physiological factors (Narinc, 2010). Though, the maximum size of an animal is determined by its genetics, other factors (e.g. nutrition, management system, temperature, humidity, prevalence of diseases and parasites, stocking density, etc.) influence whether the animal reaches its genetic potential for size or not (Tickle, 2004; Darmani *et al.,* 2010). Chicken growth curve follows a sigmoid pattern with the following characteristics: a lag phase from the period of hatch until the chick attains 10% of its final body weight, followed by an accelerating phase of growth, a point of inflection in the growth curve at which the growth rate approaches maximum (exponential growth), a phase where growth rate is decelerating, and asymptotic mature weight (stationary phase) when maximum growth is attained (Crawford, 1993, Knizetova *et al.,* 1995; Faridi *et al.,* 2010; Osei-Amponsah *et al.,* 2014; Tickle *et al.,* 2014). Understanding the biology of growth model parameters and their relationships provides a sound basis for developing a breeding strategy to modify or change the trajectory of growth. An important component of the trajectory of growth is the inflection point, which represents the point along the growth curve when the rate of growth begins to decelerate. Growth models are characterized with either fixed or variable inflection points (Karkach, 2006). There are several growth models for chickens, of which the most often used models which yield parameters that have biological interpretation are the non-linear functions (Darmani *et al.,* 2010). Although, the fitting of non-linear growth equations to data is slightly more involving than for linear models, non-linear models remain models of choice for longitudinal data of poultry, based on some specific advantages (UCLA SAS Notes, 2016), including : (1) non-linear models are often derived based on the physical basis and/or biological considerations; (2) parameters of non-linear models usually have direct interpretation in terms of the process under study; (3) constraints can be built into non-linear models, which may be more difficult in the case of linear models. More importantly, modelling growth with non-linear sigmoid functions will enable an objective comparison of the growth efficiency of chickens, and can be used to explore the desired body composition at any given age (Aggrey, 2002). Growth curve modelling can also be used to determine the efficiency of nutrient utilization and derivation of space for food requirements at different ages (Selvaggi *et al.,* 2015); for defining ages and/or weights for selection (Narinc, 2010). Furthermore, growth curve modelling can be used to match chickens' growth rates across production systems and to establish growth descriptors for local chicken genetic resources for further characterization and establishment of breed standards (FAO, 2007; Eleroglu *et al.,* 2014; Michalczuk *et al.,* 2016). Some common non-linear models for chicken growth curves include Logistics, Gompertz, Brody, Von Bertalanffy, Richard's, Negative Exponential, Morgan-Mercer Flodin, Weibull, France models and their modified forms, while some recent functions are the Hyperbolastic and Koya-Goshu models (Aggrey, 2002; Ahmadi and Golian, 2008; Narinc *et al.,* 2010; Koya and Goshu, 2013). Several authors (Adedokun and Sonaiya, 2001; Fayeye *et al.,* 2005; Olawumi *et al.,* 2008; Sola-Ojo and Ayorinde, 2009; Ogie *et al.,* 2012; Ige, 2013; Jesuyon and Salako, 2013) recommended the Fulani ecotype chicken as a potential locally adapted chicken for rural poultry development, with the potential to transform rural chicken production in Nigeria. This is because this chicken ecotype possesses good egg quality, adaptability and growth performance that may be tapped in commercial operations. However, the genetic potential of these chickens for improved body weight gain has not been fully exploited using growth model parameters. The objective of this study was therefore, to model the growth of NFEC with four non-linear functions under two production systems, with a view to establishing growth descriptors for NFEC for further characterization and establishment of breed standards.

Materials and methods

Data collection

Detailed methodology is presented in a companion paper (Aworetan and Oseni, unpublished). Two hundred-day-old chicks of Nigerian Fulani Ecotype Chicken (NFEC) were obtained from an established NFEC population at the Teaching and Research Farm, Obafemi Awolowo University, Ile-Ife, Nigeria. At day-old, each chick was weighed and tagged. The chicks were brooded for two weeks and were retained in the brooding pen till the fifth week before they were transferred to the deep litter pens. Chickens were distributed randomly into the respective units: intensive (deep-litter) and semi-intensive (pastured poultry) production system at 12 weeks of age. Distribution of chickens to outdoor pastured poultry unit was delayed till the 12th week because of susceptibility of younger chickens to predators, especially hawks, due to their small body size at younger ages. Data on body weight was taken weekly from day-old till the birds were 20 weeks of age.

Statistical procedures and data analysis

Four non-linear functions including Gompertz, Logistic, Bertalanffy and Richard's were fitted using the NLIN procedure of SAS® (2003). The growth model equations, formula for age and weight at inflection and relative growth rate are presented in Table 1.

Table 1: Growth model equations

Model	Equation	Inflection time	Weight at inflection	Relative growth rate
Gompertz	$W_t = Ae\text{-}^{Be(-kt)}$	A/e	$\ln{(B)}/k$	$k\,(\frac{A-W(t)}{A})$
Logistic	$W_t = A/1+Be^{-kt}$	$A/2$	$\ln{(B)}/k$	$k*\log\,(\frac{A}{W(t)})$
Von Bertalanffy	$W_t = A(1-Be^{-kt})^3$	$8/27\ (A)$	$\frac{1}{k} ln.3(B)$	$3k\left[(\frac{A}{W(t)})^{1/3} - 1\right]$
Richard's	$A(1\tilde{a}Be^{-kt})^d$	$A/(d+1)^{1/d}$	$\frac{1}{k} * \ln\lvert d/B \rvert$	$dk\left[(\frac{A}{W(t)})^{1/d} - 1\right]$

Where W_t: body weight at age t weeks; t is the bird's age; A is the asymptotic or mature weight when age (t) approaches infinity; B is a scaling parameter (constant of integration) related with initial values of weight; k is the maturity index (maximum relative growth) and; d is shape parameter which allows a variable inflection point in the case of Richard's model while e is the Euler's Number=2.71828 (Koya and Goshu, 2013).

Selection of best-fit model

The most appropriate model(s) for growth parameters of NFEC was selected using Goodness-of-Fit tests including coefficient of determination (R^2), adjusted R^2, mean square error (MSE), residual standard deviation (RSD), Akaike Information Criterion (AIC) and Bayesian Information Criterion (BIC). Criteria for model selection and the formula used are presented in Table (2). According to Kaps and Lamberson (2002), a model with the largest R^2 or Adj. R^2 statistic is the best, while a model with the lowest MSE, AIC or BIC is the most superior model.

Table 2: Formula for goodness-of-fit tests

Model selection Criteria	Abbrev.	Equation
Coefficient of determination	R^2	$1-\left(\frac{SSE}{SST}\right)$
Adjusted coefficient of determination	Adj.R^2	$R^2-\left(\left(K-1/_{n-k}\right)(1-R^2)\right)$
Mean square error	MSE	$\frac{SSE}{n-k}$
Residual standard deviation	RSD	$\frac{(SSE)^{1/2}}{(n-k)^{1/2}}$
Akaike information criterion	AIC	$n.\ln\left(SSE/_n\right)+2k$
Bayesian information criterion	BIC	$-2\log(L)+K\log(N)$

k is the number of parameters, n is the sample size, SSE is the Sum of Squares Error, SST is the Total Sum of Square and L is the maximum value of the likelihood function for the model (Kaps and Lamberson, 2002; Eleroglu *et al.*, 2014).

Results and discussion

Growth model parameters using Gompertz, Logistic, Bertalanffy and Richard's functions

Table (3) shows the estimated growth model parameters for male and female Nigerian Fulani ecotype chickens reared in the intensive and pastured poultry systems using Gompertz, Logistic, Bertalanffy and Richard's growth functions. For all the models, parameter (A) which is the asymptotic weight (or maximum stationary weight) for male chickens in the intensive and pastured poultry systems were in the ratios 2185g:2015g, 2014g:1880g, 2335g:2200g, and 2417g:2255g, respectively while corresponding parameter B (the scaling parameter), were 3.617:4.095, 15.83:19.79, 0.77:0.86 and 15.83:19.08. Estimates for parameter K (the maturity index) were 0.09:0.11, 0.17:0.19, 0.07:0.08 and 0.17:0.19, respectively. Parameters A, B and K values for the female chickens under intensive and pastured poultry were 1415g:1282g, 1324g:1206g, 1490g:1323g and 1550g:1412g. The corresponding parameter B values were in the ratios of 3.15:4.13, 11.09:17.56, 0.71:0.89 and 17.09:17.56 while parameter K values were 0.09:0.14, 0.16:0.23, 0.07:0.11 and 0.16:0.23 respectively. Values for parameters B and K cannot be compared directly among models since both are determined by the derivatives of the growth functions. Hence, they are distinctive for each model although some models have close ranges for this parameter. The estimate for parameter B was in the same range of ≤ 20 for Logistic and Richard's models. However, for all the models, values of parameter K were significantly higher than zero, implying a relative growth rate from hatch to maximum growth. Parameters B and K were the same for both Logistic and Richard's but the shape parameter (d) of Richard's model which allows for variable inflection point accounted for the difference in the asymptotic weight predicted by both models. The shape parameter d, specific for Richard's model were 1.2 and 1.17 for male and female chickens respectively in the two production systems. There was no significant difference among parameters A, B and K, based on production systems but parameter A values were significantly different for both sexes for all the models while estimates for parameters B and K were not significantly different between the two production systems and sexes but were significantly different among the models.

The values of parameter A obtained in this study using Gompertz model is consistent with studies carried out on some indigenous chickens in Kenya, Ghana and Tanzania by Ngeno *et al.,* (2010), Osei-Amponsah *et al.* (2014) and Guni *et al.* (2013), respectively. Similarly, a study on indigenous chicken breeds in China by Zhao *et al*. (2015) reported marginally higher values ranging between 2423.34g to 2968.26g for parameter A. Furthermore, values for parameter A, obtained in this study for Logistic model compared well with values of 2192.7g:1693g, 2906.35g:2133.33g and 2357g:1640g for male:female chickens, respectively as reported by Aggrey (2002); Eleroglu *et al.* (2014) and Rizzi *et al.* (2013), for some Athens-Canadian, Turkish, and Italian local chicken populations, respectively. However, a similar study conducted on some non-descript Italian chicken population by Selvaggi *et al.,* (2015) reported high asymptotic weight for both male and female chickens based on Gompertz and Logistic models (values of 5000.26g:4839.85g and 5661.58g:5870.39g, respectively). Parameter A obtained with Von-Bertalanffy model in this study compares well with values of 3685.37g and 2172.89g reported by Zhao *et al.* (2015) and Ngeno *et al.* (2013) for some local chicken populations of China and Kenya respectively, while a much higher value (4701.084g:3100g) for female:male was reported by Yang *et al.,* (2006). In the case of Richard's model, parameter A, values estimated in this study is in consonance with 2656g:1894g and 1752.5g:1304.3g reported for male:female chickens by Rizzi *et al.* (2013) and Osei-Amponsah *et al.* (2014) for some local chickens of Italy and Ghana, respectively, whereas, values of 5729.99g:3847.68g obtained with the same model by Michalczuk *et al.* (2016) on progenies of an F_2 cross of a local chicken with a fast-growing commercial chicken was very high. The variation that exist in the values of parameter A as estimated by each model could be breed (or ecotype) specific. Chickens that attain the estimated maximum growth at earlier ages can be selected for breeding since these growth parameters are highly heritable (Falconer and Mackay, 1998).

Table 3: Least squares means and standard errors of growth curve parameters by sex of chickens and production systems

Model	PS	A	B	K	A	B	K
		Male			Female		
Gompertz	Int	2185.46±85.09	3.62±0.15	0.09±0.00	1415.00±63.20	3.15±0.17	0.09±0.01
	Past	2015.00±42.16	4.09±0.15	0.11±0.00	1282.10±22.73	4.13±0.17	0.14±0.01
Logistic	Int	2014.10±61.45	15.83±1.60	0.17±0.01	1324.40±65.20	11.09±1.52	0.16±0.01
	Past	1879.80±45.31	19.08±1.74	0.19±0.01	1206.90±26.67	17.56±1.83	0.23±0.01
Bert.	Int	2335.50±94.02	0.77±0.02	0.07±0.01	1490.10±70.01	0.71±0.03	0.07±0.01
	Pas	2117.70±64.06	0.86±0.03	0.08±0.00	1323.90±32.04	0.88±0.03	0.11±0.01
Richard	Int	2417.00±73.68	15.82±1.55	0.17±0.08	1550.00±76.28	17.09±1.52	0.16±0.01
		2255.70±54.37	19.08±1.74	0.19±0.01	1412.10±31.20	17.56±1.83	0.23±0.01

PS=production system, A is the asymptotic weight, B is the model scaling parameter and K is the maturity index . Int=Intensive, Pas=Pasture and Bert=Bertalanffy.

Growth descriptors for NFEC: Age and body weight at inflection point

Table (4) contains the age and body weight at inflection point for NFEC as estimated with Gompertz, Logistic, Bertalanffy and Richard's models. Age at inflection point for NFEC ranged between 11 and 16 weeks for male chickens and 9 to 15 weeks for female chickens in both intensive and pastured poultry production systems respectively. The corresponding weight at inflection ranged between 627g and 1337g, and 392g and 662g. The age at inflection point for the chickens on pasture was about 1 to 2 weeks earlier than their counterparts in intensive system for both male and female chickens except for the Gompertz model which estimated the same age at inflection point for the male chicken in intensive and pastured poultry. The inflection points (age and weight) obtained using Bertalanffy model for both male and female chickens were the most divergent. It was observed that models with similar parameter K (maturity index) values have close range of inflection points. An example of such a phenomenon is the estimates obtained with Logistic and Richard's functions. This can be explained based on the findings of Aggrey (2002) that growth model parameters have pronounced correlation and that the inflection point strongly influences the constant value of the growth rate and the mature body weight. The inflection age predicted in this study for male:female with Gompertz model compared well with values 9:10, 10:11, 12:11, 13:12, 10.6:10.9 and 12.04:12.10 weeks reported by Aggrey (2002), Yang *et al.* (2007), Rizzi *et al.* (2013), Eleroglu *et al.* (2014), Osei-Amponsah *et al.,* (2014) and Selvaggi *et al.* (2015), respectively, for slow growing chickens.

Table 4: Age (weeks) and Weight(g) at Inflection point

Model	Ps	T_i (weeks)	W_i (g)	T_i (weeks)	W_i (g)
		Male		**Female**	
Gompertz	Intensive	13	804	12	521
	Pasture	13	741	10	472
Logistic	Intensive	16	1007	15	662
	Pasture	15	940	12	603
Bertalanffy	Intensive	12	692	10	442
	Pasture	11	627	9	392
Richard	Intensive	15	1337	14	565
	Pasture	14	1231	12	507

PS=production system; T_i is the inflection age in weeks and W_i is the weight at inflection in (g)

Selection of best fit model(s) for NFEC

Sequel to the fitting of NFEC growth data with four non-linear growth models including Gompertz, Logistic, Bertalanffy and Richard's, there is a need to recommend the best fit model(s). Such recommendations are based on goodness-of-fit tests which include Coefficient of Determination (R^2), Adjusted R^2 (Adj R^2), Mean Square Error (MSE), Residual Standard Deviation (RSD), Akaike Information Criterion (AIC) and Bayesian Information Criterion (BIC) (Kaps and Lamberson, 2002). Table 5 shows the values of the various model selection criteria used, based on sexes of chicken and production systems. The high R^2 and Adj R^2 values obtained showed that all the models fitted the growth data of NFEC suitably, indicating that ≥ 96% of the variability in the body weight of NFEC was explained by the models. Decision for the best fit model was not based on R^2 due to its limitation in not penalizing over-parameterization.

Based on AIC, BIC and RSD, the model with best fit was Gompertz for male chickens under the intensive and pastured poultry production systems. In the case of female chickens in the intensive system, Gompertz was also the best fit model based on AIC and Bertalanffy was the best fit model based on BIC and RSD. Gompertz also emerged as the best fit for the female chickens under the pastured poultry system, based on AIC, BIC and RSD. Thus, Gompertz and Bertalanffy models were the best fit growth functions for NFEC based on these goodness-of-fit tests. Studies on some local chickens in China, Kenya, Turkey, Ghana and Italy by Yang *et al.,* (2006), Ngeno *et al.* (2010), Eleroglu *et al.* (2014), Osei-Amponsah *et al.,* (2014) and Selvaggi *et al.* (2015) reported that Bertalanffy, Gompertz, and Richard's (in that order) as the best fit models. From the literature, the Gompertz model has been ranked consistently as the best fit growth model for local and exotic chickens, despite its fixed inflection point at 1/e (= 0.368) of the asymptotic weight.

Table 5: Best fit model selection for Nigerian Fulani ecotype chicken using goodness-of-fit tests values arranged in increasing order

PS	R^2	Adj. R^2	Order	MSE	AIC	Order	BIC	RSD	Order
Intensive	0.9921	0.9689	Lg	1567.06	173.47	Gp*	185.47	41.77	Bev*
	0.9922	0.9690	Rch	1744.80	176.04	Bev	190.35	46.24	Gp
	0.9957	0.9831	Gp	3916.20	195.38	Lg	204.88	62.58	Lg
	0.9965	0.9862	Bev*	4111.99	195.40	Rch	208.06	64.13	Rch
	0.9976	0.9907	Lg	554.00	148.70	Gp*	157.97	23.55	Gp*
Pasture	0.9977	0.9908	Rch	849.60	158.86	Bev	168.20	29.15	Bev
	0.9983	0.9933	Bev	1164.40	166.37	Lg	175.78	34.13	Lg
	0.9989	0.9956	Gp*	1223.18	166.43	Rch	178.96	34.97	Rch

*Gp=Gompertz, Lg=logistic, Bev= Bertalanffy, Rch=Richard models and PS=production system while R^2, Adj.R^2, MSE, RSD, AIC and BIC are Coefficient of Determination, Adjusted Coefficient of Determination, Mean Square Error, Residual Standard Deviation, Akaike Information Criterion, Bayesian Information Criterion respectively. * =best fit model*

Correlation coefficients among model parameters

Correlation coefficients among model parameters are presented in Table (6) Correlation coefficients between parameters A (asymptotic weight) and B (constant of integration), ranging from -0.07 to -0.54 were consistently negative for both male and female chickens, between production systems and in all models. High and positive correlation coefficients were obtained between parameters B and K for all the models, ranging from 0.73 to 0.86. The pronounced negative correlation coefficient between parameters A and B indicates that the higher the value of the constant of integration, the lesser the time it will take to reach mature weight. This confirms the report of Aggrey (2002) that the position of the inflection point strongly influences the constant value of the growth rate and mature body weight. The negative correlation coefficient also justifies the relationship between the weight at hatch and the constant of integration (parameter B). The negative correlation coefficient between parameters A and K showed that the rate of growth is a logarithmic function of weight, changing per unit time. The high and positive correlation coefficient between parameters B and K implies that the growth rate for the different phases is highly dependent on the model since parameter B is a scaling parameter specific to each model and may assume different values depending on the growth function. Results obtained in this study are in consonance with the report of Ngeno *et al.,*

(2010) who obtained negative correlation coefficients between parameters A and K, with values ranging from -0.63 to -0.99. The author also reported the least value for correlation coefficients between parameter A and K for the Logistic model.

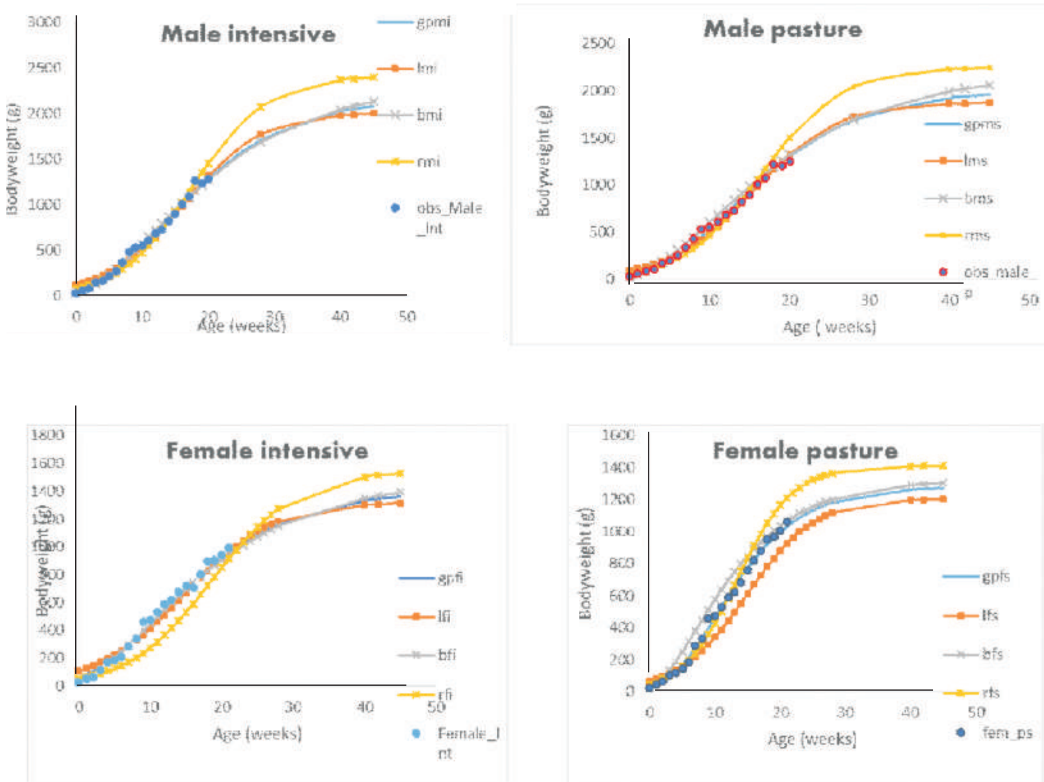
Table 6: Correlation coefficients among growth model parameters of Gompertz, Logistic, Bertalanffy and Richard's model

Ps	Gp	Log	Bert	Rch	Gp	Log	Bert	Rch
	Male				**Female**			
				Parameters A and B				
Intensive	-0.35	-0.08	-0.48	-0.08	-0.31	-0.07	-0.42	-0.07
Pasture	-0.40	-0.16	-0.53	0.16	-0.44	-0.29	-0.54	0.29
				Parameters A and K				
Intensive	-0.82	-0.60	-0.60	-0.84	-0.84	-0.68	-0.89	-0.68
Pasture	-0.80	-0.62	-0.86	-0.62	-0.80	-0.68	-0.85	-0.68
				Parameters B and K				
Intensive	0.78	0.80	0.79	0.80	0.73	0.73	0.74	0.73
Pasture	0.84	0.84	0.85	0.85	0.85	0.86	0.86	0.85

Gp=Gompertz, Log=Logistic, Bev= Bertalanffy, Rch=Richard Koy=Koya-Goshu model and PS= Production system

Growth curve of the Nigerian Fulani ecotype chicken under two production systems

Graphical representation of the Nigerian Fulani ecotype chicken growth rate patterns using model parameters (Fig. 1 to 4) for male and female chickens, respectively showed the dependency of body weight on age over time. Body weight increases with age but at different rates which slightly differed from one model to the other except for Richard's model with higher body weight predicted from 4 weeks upward. The interplay of growth curves for sexes of chicken and production systems presented in Fig. (1 to 4) showed that the growth curve of both male and female chickens in the intensive and pasture systems was the same except for some departure points in curvature before the 28th week. However, from the curve, it is depicted that after 8 weeks, there are points at which the trajectory for those on pasture and intensive meet based on predicted pattern by Gompertz. The maximum stationary phase began in the 28th and 25th week for female chickens on pastured poultry and intensive systems respectively, based on Bertalanffy and Richard's models. The growth curve Fig. (1) and (2) showing the nexus of Gompertz, Logistic, Bertalanffy and Richard's model for the male chicken in the intensive system exhibited the same trend up to the 16th week while the Richard's model surpassed all other models in weight gain. Nevertheless, at 40 weeks, the maximum stationary weight was attained based on the relative growth curves pattern depicted in Fig. (5) and (6). The same growth pattern was also observed for female chickens in the intensive system Fig. (3) and (4). Growth pattern of male chickens in the pastured poultry system was not different from those in the intensive but variations exist in the values of parameters A, B and K for all the models. The graphical representation (growth curve), being an outcome of the model parameters and the growth data supplied, can be used in inferring the suitability of a particular model for the growth data in conjunction with other statistical goodness-of-fit tests, implying that the curve that is close to the observed data has the best fit.



IT= Intensive, PS= pastured poultry system, gmi=Gompertz male intensive, gfi=Gompertz female intensive, gpms=Gompertz male pastsure, gpfs=Gompertz female pasture while in all (g l, b and r) represent Gompertz, Logistic, Bertalanffy and Richard

Figures 1 to 4: Growth curves of Nigerian Fulani ecotype chicken (1=upper right; 2=upper left; 3=lower left and 4=lower right)

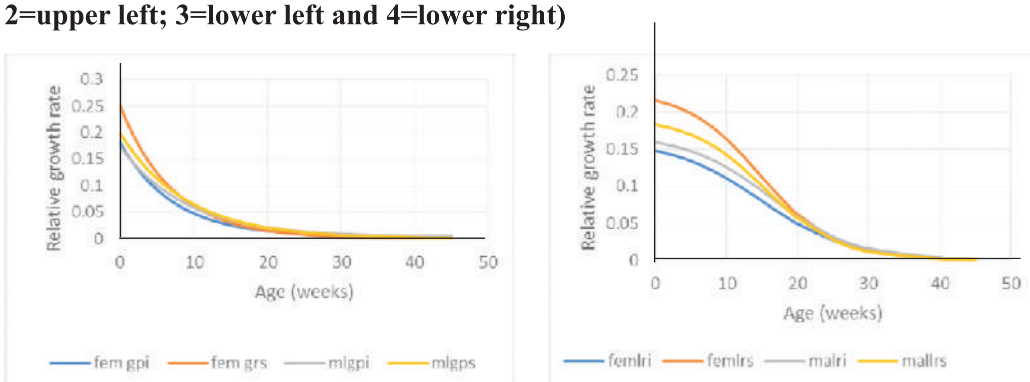


Figure 5 and 6: Relative growth curves of Gompertz and Logistic model, respectively

The study estimated growth parameters and growth curves for NFEC. The growth parameters can be used as guidelines for exploiting its growth potentials for overall genetic improvement. The expected values for body weight across weeks (0 to 20) predicted by the four growth functions for the two production systems were at close range. Gompertz and Bertalanffy models were confirmed as the best fit growth functions for growth analysis of NFEC data.

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