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Comparison of nonlinear functions in male and female chickens at different seasons using restricted Maximum Likelihood Approach

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Abstract

Weekly body weight data from 133 offsprings of Bovan Nera (NB), 93 of White Leghorn (WL), 105 of Giriraja (GR), 197 of Naked Neck (NN), 164 of Frizzle Feather (FF), 186 of Normal Feather (NF) and 115 of improved indigenous FUNAAB Alpha chicken (BA) were used for the study. The birds were individually wing tagged at day old for proper identification purpose. They were brooded in a brooding cage for the first three weeks then housed and reared on a deep litter until twenty weeks of age. Feed and water was given ad libtum. Weekly weight gain of the birds were subjected to four nonlinear growth models, Logistics, Gompertz, Richards and Bertalanffy to estimate the growth curve of the birds using fixed effect model and the procedure of NLIN (Marquart algorithm) The growth curves as predicted by the four models considered showed that both male and female GR followed by NB expressed better growth rate and highest weight at 20 weeks of age compared to other genotypes during late dry season and early wet season while the growth curve of WL in female and, WL and NF in male during late dry season had the lowest predicted curve. The predicted growth curve during early wet season had NF presenting the lowest growth curve for most of the model. The predicted growth curve showed a more consistence output in Logistic and Gompertz model. The goodness of fit favoured Gompertz as the model of best fit for predicting growth curve in both local and locally adapted chickens.

Keywords: *Growth curve, Nigerian Indigenous chickens, Restricted Maximum Likelihood function,*

Introduction

Growth curves are usually considered infinite-dimensional or function-value traits, because they are described by an infinite set of measurement (Ozoje *et al*., 2007). This shows that growth curves are important to breeding plans because they shift in response to selection (Gwaze *et al*., 2002). Due to the differential growth of the body parts of any poultry breed, one cannot measure continuously most of these growth processes, it is therefore, preferable to model increase in body weight over a period of time by growth model. Measurement of growth is analyzed with respect to time (age) using non-linear growth models which can best described the sigmoid shaped pattern of growth in poultry. However, parameters included within any non-linear growth models varies with model of choice. Commonly used examples of these functions include three parameters equations, Gompertz, Bertalanffy, Logistic and four parameter Richards equation. With any non-linear model, the minimal parameter components describe the chicken initial weight, maturing rate and the final (asymptotic) weight as time approaches infinity. The curves start as some fixed point, growth rate then increases at an increasing rate up to an inflection point after which it increases at a decreasing rate asymptotically to a final value (Ratkowsky, 1983). Individual growth curve parameters, both basic and derived are suitable phenotypic variables for the assessment of growth course and early maturity (Lopez de Torre and Rankin, 1978, Kratochvilova *et al*., 2002). Growth performance in poultry production is a blend of both the genetic and environmental element. Efficiency of body-weight growth in poultry depends on understanding how genetic and environmental elements can be used to manipulate growth attributes and maturing independently of mature weight thereby altering the shape of the growth curve.

This study aimed at examining the seasonal differences between male and female genotypes and models comparison based on predicted growth curves.

Materials and methods

Experimental Bird

Weekly body weight data from 133 offspring of Bovan Nera (NB), 93 of White Leghorn (WL), 105 of Giriraja (GR), 197 of Naked Neck (NN), 164 of Frizzle Feather (FF), 186 of Normal Feather (NF) and 115 of improved indigenous FUNAAB Alpha chicken (BA) were used for the study. The offspring were obtained through the process of artificial mating. Fertile eggs were collected daily from the inseminated hens and stored in a cool environment (10-14^{0}C and 75-80% relative humidity) for seven days so as to obtain substantial number of eggs before incubation. The chicks were hatched in batches, between late dry season (January – March) and early wet season (April – June).

Management of the bird

The birds were individually wing tagged at day old for proper identification purpose. They were brooded in a brooding cage for the first three weeks then housed and reared on a deep litter until twenty weeks of age. Feed and water were given *ad libitum.* The birds were fed chicks mash diet (21.49% crude protein and 2816.45kcal/kg metabolizable energy) from 0-8 weeks of age and grower's mash (16.90% crude protein and 2715.35kcal/kg ME) thereafter. Drugs and vaccines were administered accordingly.

Data collection and analysis

Weekly weight gain of the birds were subjected to four nonlinear growth models, Logistics, Gompertz, Richards and Bertalanffy to estimate the growth curve of the birds using fixed effect model. The mathematical notations of the growth models are presented in Table 1. According to Wilson (1997), a typical growth curve of poultry generally compose of the following features, growth from hatching (t = 0), an exponential rate of growth peaked at an inflection point at which weight is maximum, a decaying phase during which growth rate increases at a decreasing rate and a limiting value called asymptotic (mature or final) weight.

Growth curve parameters (*A*, *B*, *k* and *m*) for the Logistic, Gompertz, Richards or Bertalanffy growth models were estimated for each chicken genotype using the procedure of NLIN (Marquart algorithm) (SAS Institute Inc., 2000).

Table 1. Equations for cases of Logistic, Gompertz, Richards and Bertalanffy model

Model	Mathematical function
Logistic model	$BW_{ij} = A_i\ (1+ B_i\ exp\{-K_it_{ij}\})^{-1}$
Gompertz model	$BW_{ij} = A_i\ exp(- B_i\ exp\{-K_it_{ij}\})^{-1}$
Richards model	$BW_{ij} = A_i\ (1+ B_i\ exp\{-K_it_{ij}\})^{(1/m)}$
Bertalanffy model	$BW_{ij} = A_i\ (1- B_i\ exp\{-K_it_{ij}\})^{-3}$

Where BW_{ij} = body weight of the bird at age (week) t_{ij};
A = asymptotic weight ($t_i = \infty$);
B = integration constant ($t_i = 0$);
k = maturing rate;
t = age of the bird;
m = shape parameter determining the position of the inflection point at which the auto acceleration growth phase passes into the auto retardation phase.

Results and Discussion

Male Genotype

Late Dry Season

Figures 1, 2, 3 and 4 shows the 20-week growth curves for male chickens reared during the late dry season as predicted by Logistic, Gompertz, Richards and Bertalanffy growth model respectively. The growth curves showed that GR expressed better growth rate and highest weight at 20 weeks of age for all the models while other genotypes had closely related growth rate spanning the day old to 15 weeks in Logistic, 13 weeks in Gompertz and 10 weeks in Bertalanffy model. Richards model predicted wide variations between the growth patterns of all the genotypes (Figure 3) compared to the other three models. The superior performance recorded in GR and NB could be due to the fact that they have been bred for faster growth (Peters *et al*., 2005). Next to GR in growth rate and final 20-week weight was NB but with a weight difference of between 400g in Bertalanffy to 800g in Richards. The growth performance of the FUNAAB Alpha genotype (BA) was better than the three indigenous genotypes (NN, FF and NF) and WL in all the models. With the exception of Richards model, WL produced the least growth rate and 20-week body weight after NF. However, among the indigenous genotypes, FF produced better performance with respect to final body weight. However, among the indigenous breeds, FF followed by NN chickens performed relatively better than the NF chicken which is attributable to the existence of major genes of the frizzling and the naked neck genes. This was in line with reports of Ajang *et al.* (1993) where they attributed the superiority of these major genes over their Normal feathered counterparts to reduce feathering with its consequent conservation of protein, which ought to have been used for feather growth.

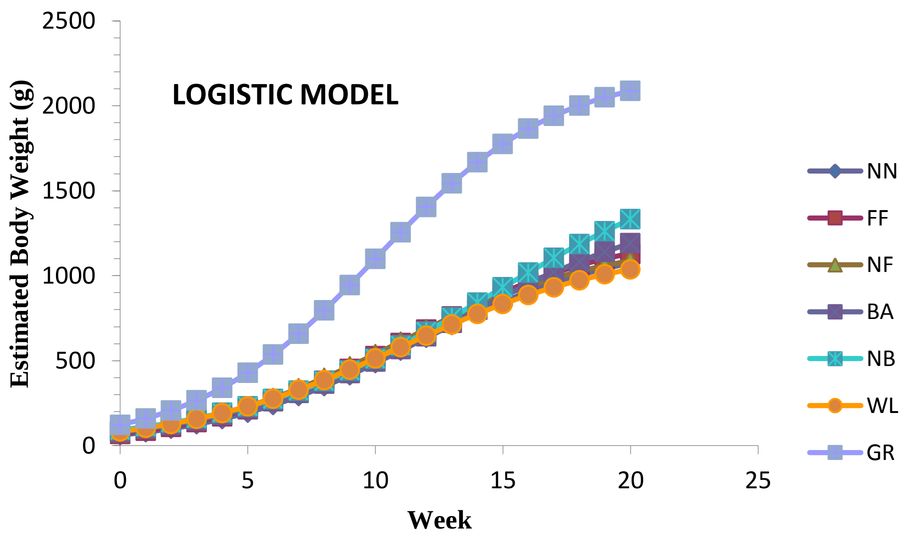

Figure 1. Logistic predicted 20-week growth curves for male chickens during late dry season (between January and March)

NN=Naked Neck, FF=Frizzle Feathered, NF=Normal Feathered, BA=FUNAAB Alpha, NB=Nera Black, WL=White Leghorn and GR=Giriraja,

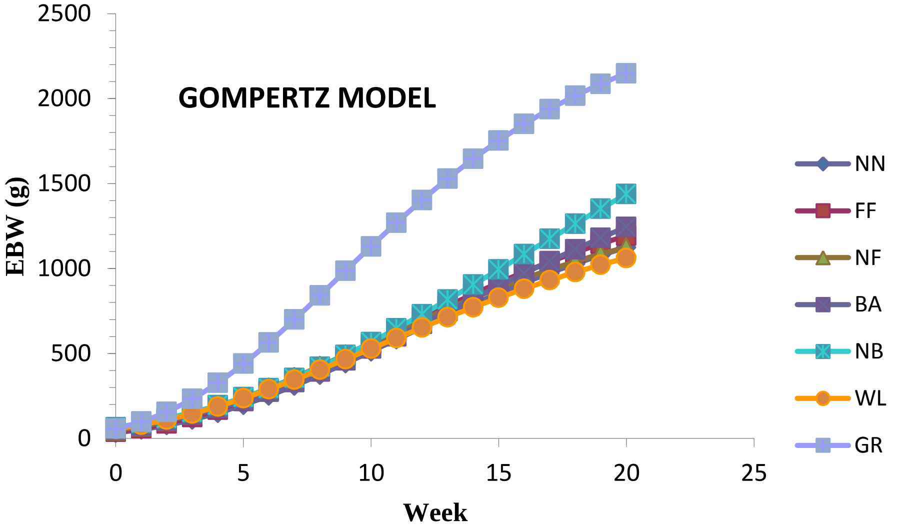

Figure 2. Gompertz predicted 20-week growth curves for male chickens during late dry season (between January and March)
NN=Naked Neck, FF=Frizzle Feathered, NF=Normal Feathered, BA=FUNAAB Alpha, NB=Nera Black, WL=White Leghorn and GR=Giriraja,

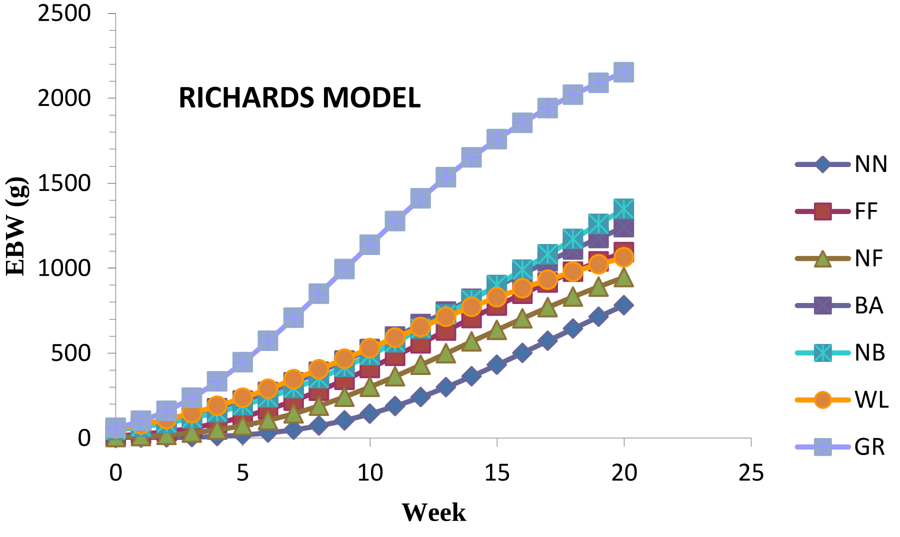

Figure 3. Richards predicted 20-week growth curves for male chickens during late dry season (between January and March)
NN=Naked Neck, FF=Frizzle Feathered, NF=Normal Feathered, BA=FUNAAB Alpha, NB=Nera Black, WL=White Leghorn and GR=Giriraja,

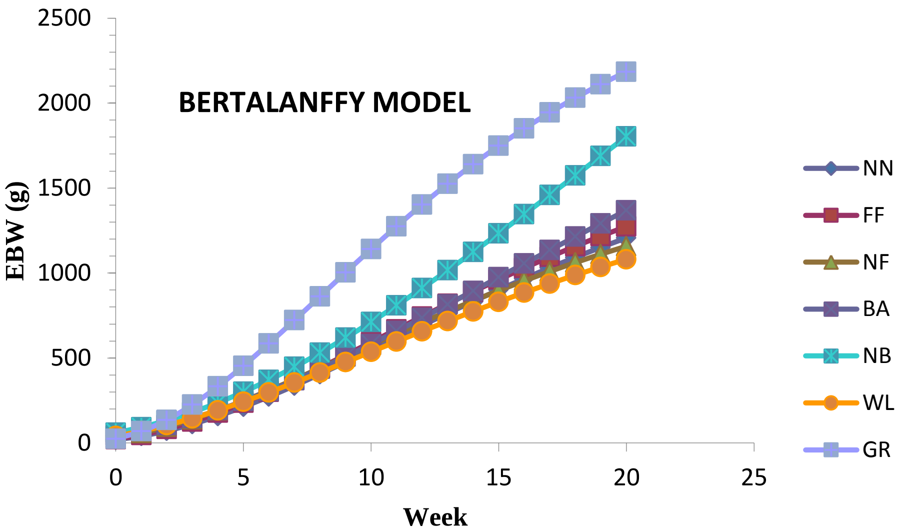

Figure 4. Bertalanffy predicted 20-week growth curves for male chickens during late dry season (between January and March)
NN=Naked Neck, FF=Frizzle Feathered, NF=Normal Feathered, BA=FUNAAB Alpha, NB=Nera Black, WL=White Leghorn and GR=Giriraja,

Male genotype

Early wet season

The growth pattern of male chickens recorded during the early wet season for all the models are as shown in Figures 5, 6, 7 and 8. The growth curve estimated for GR, though better than other genotypes but performed less than what was achieved during the late dry season. WL which had the least weight during the late dry season performed better during the early wet season to come second after GR along with NB and BA for all the models. The predicted growth curve of BA was better than the WL chicken and the indigenous chickens (NN, NF and FF). One of the indigenous genotypes, NF, had the least final 20-week body weight gain. The other two indigenous genotypes, FF and NN, are relatively closer in weight to the BA, although NN was slightly higher than FF. the growth rate of all the genotypes with the exception of GR were closer from start up till the 15th week in Logistic (Table 5), 13th week in Gompertz (Table 6) and the 14th week in Richards (Table 7), but, NF drop below others at the 20th week. However, in Bertalanffy model, decline in growth rate started for the indigenous genotype at the 8th week of age. In all, a variance of 600g was recorded between GR and the second best genotype (NB).

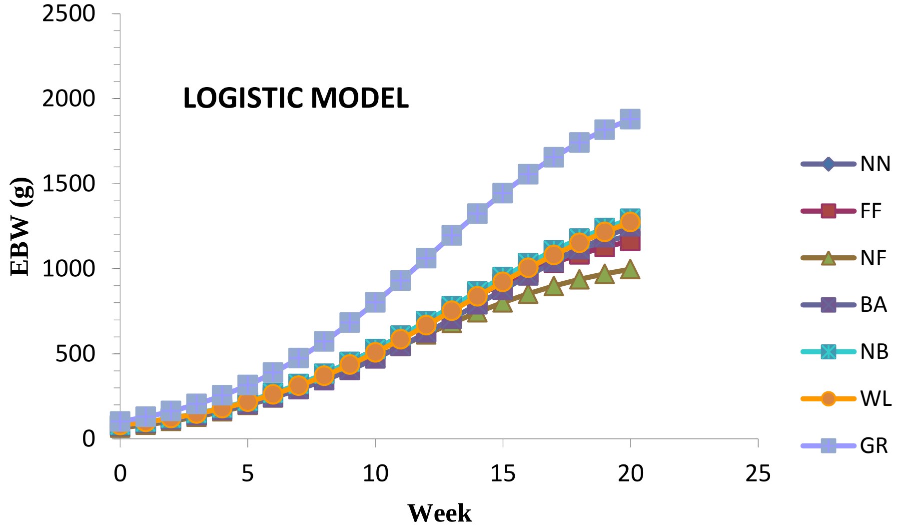

Figure 5. Predicted 20-week growth curves of male chickens reared during early wet season (between April and June)
NN=Naked Neck, FF=Frizzle Feathered, NF=Normal Feathered, BA=FUNAAB Alpha, NB=Nera Black, WL=White Leghorn and GR=Giriraja,

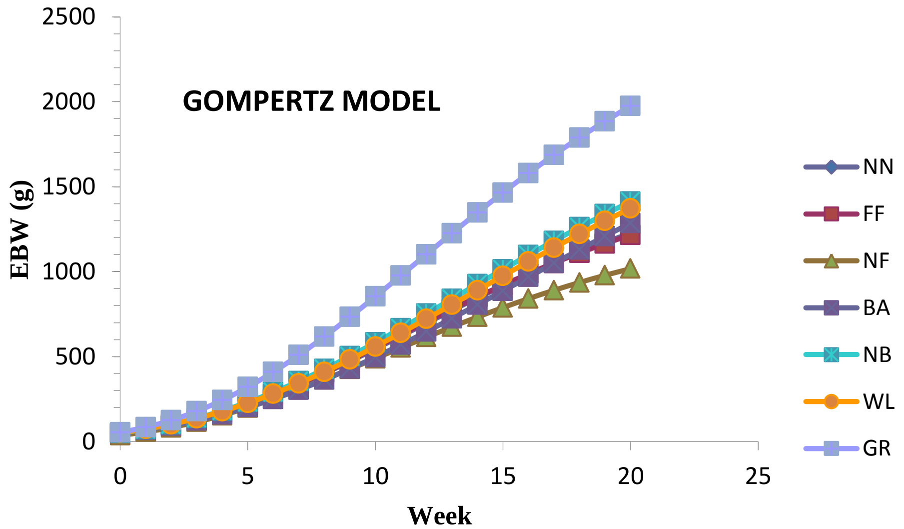

Figure 6. Predicted 20-week growth curves of male chickens reared during early wet season (between April and June)
NN=Naked Neck, FF=Frizzle Feathered, NF=Normal Feathered, BA=FUNAAB Alpha, NB=Nera Black, WL=White Leghorn and GR=Giriraja,

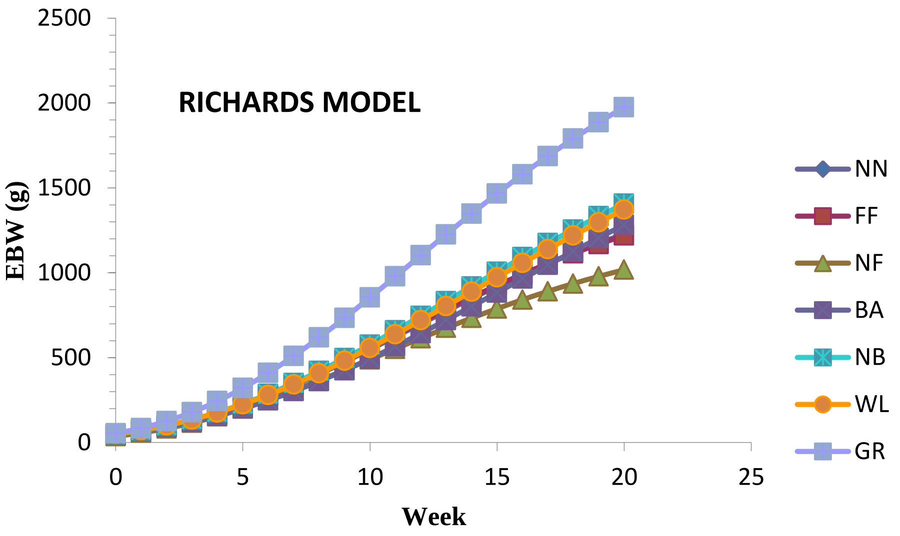

Figure 7. Predicted 20-week growth curves of male chickens reared during early wet season (between April and June)
NN=Naked Neck, FF=Frizzle Feathered, NF=Normal Feathered, BA=FUNAAB Alpha, NB=Nera Black, WL=White Leghorn and GR=Giriraja,

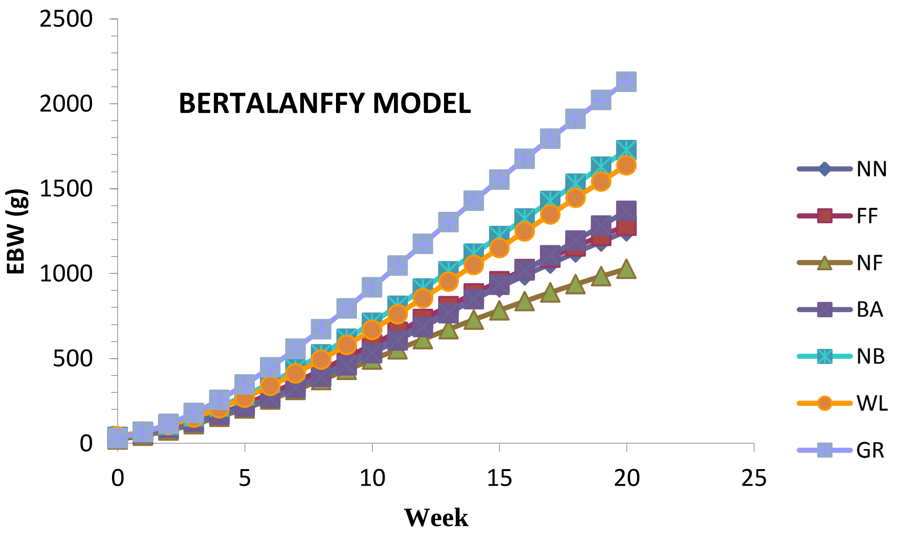

Figure 8. Predicted 20-week growth curves of male chickens reared during early wet season (between April and June)
NN=Naked Neck, FF=Frizzle Feathered, NF=Normal Feathered, BA=FUNAAB Alpha, NB=Nera Black, WL=White Leghorn and GR=Giriraja,

Female genotype

Late dry season

Female growth curves as predicted during the late dry season are as shown in Figures 9, 10, 11 and 12 for Logistics, Gompertz, Richards and Bertalanffy growth model respectively. The graphical representation of the growth curve in this study showed that all the models predicted the highest estimated body weight at 20 weeks in both male and female GR chicken followed by NB in both late dry and early wet season. The growth patterns as presented for Logistic, Gompertz and Bertalanffy were similar for all genotypes with GR having the highest 20-week body weight followed by NB with a slightly weight difference of close to 600g. The three indigenous genotypes (NN, FF and NF) and BA had closely related growth rate and body weight attained at 20 weeks of age. WL had the lowest growth rate and body weight at 20 weeks of age for all the models except in Richards model where it came second after GR. The growth paterns observed in Richards models during this season was the lowest among the other models leaving the highest 20-weeek body weight gain at 1300g while the lowest in NB was 200g. The performance of WL was poor during the late dry season as predicted by Logistic, Gompertz and Bertalanffy. From all the growth curves, it was observed that male chickens attained the highest estimated 20-week body weight compared to female chickens. This explains the factor of sexual dimorphism (Aggrey and Cheng, 1994; Aggrey *et al*., 2003).

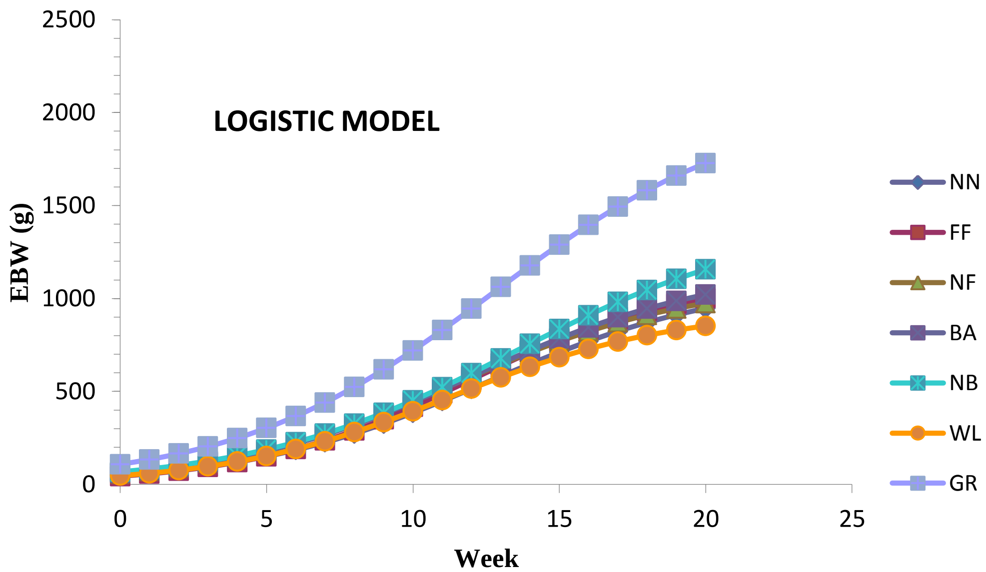

Figure 9. Predicted 20-week growth curves of female chickens reared during late dry season (between January and March)

NN=Naked Neck, FF=Frizzle Feathered, NF=Normal Feathered, BA=FUNAAB Alpha, NB=Nera Black, WL=White Leghorn and GR=Giriraja,

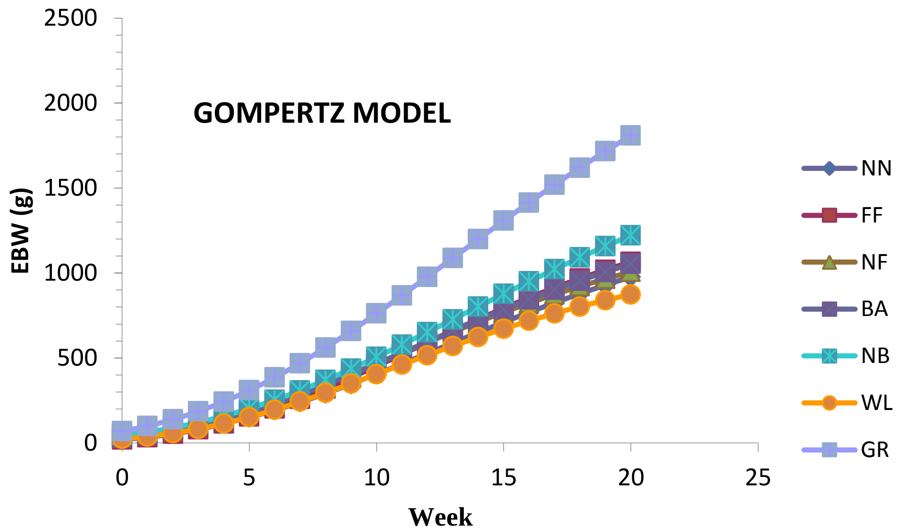

Figure 10. Predicted 20-week growth curves of female chickens reared during late dry season (between January and March)
NN=Naked Neck, FF=Frizzle Feathered, NF=Normal Feathered, BA=FUNAAB Alpha, NB=Nera Black, WL=White Leghorn and GR=Giriraja,

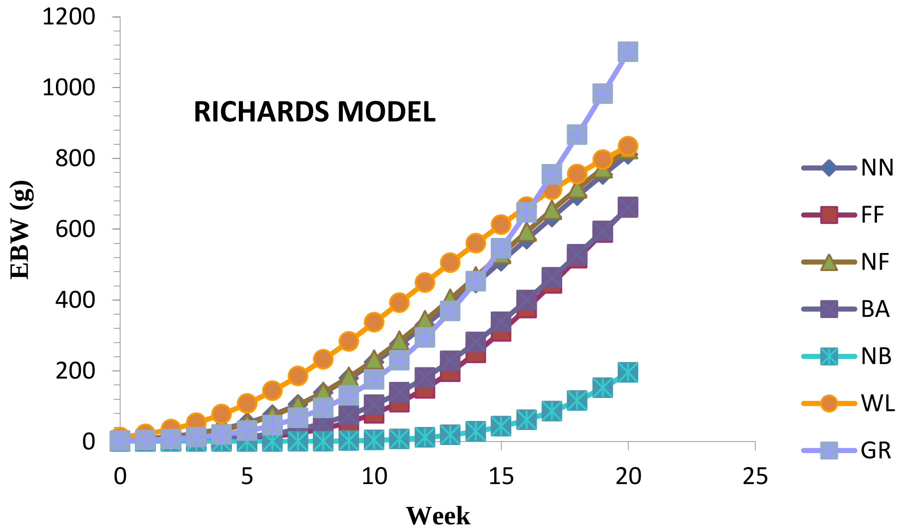

Figure 11. Predicted 20-week growth curves of female chickens reared during late dry season (between January and March)
NN=Naked Neck, FF=Frizzle Feathered, NF=Normal Feathered, BA=FUNAAB Alpha, NB=Nera Black, WL=White Leghorn and GR=Giriraja,

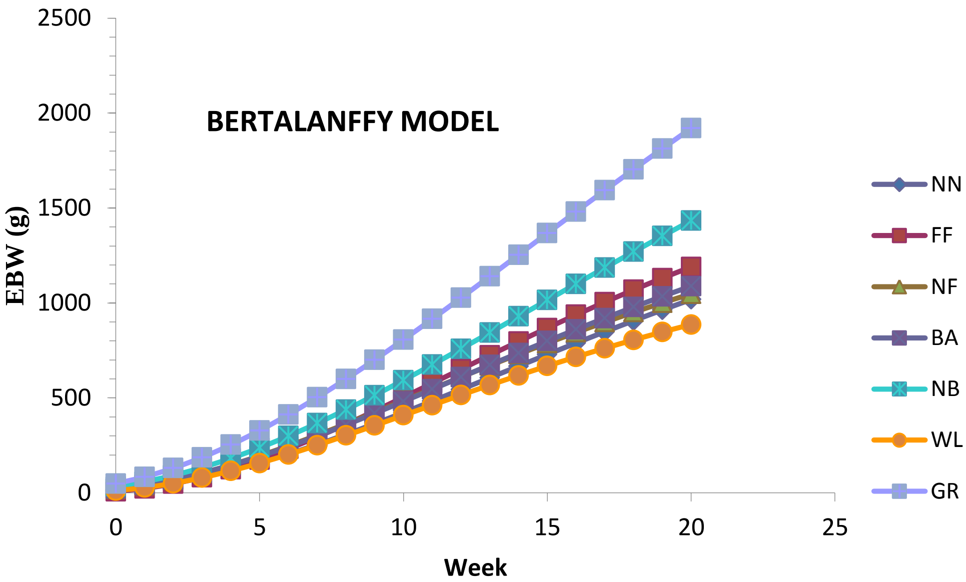

Figure 12. Predicted 20-week growth curves of female chickens reared during late dry season (between January and March)

NN=Naked Neck, FF=Frizzle Feathered, NF=Normal Feathered, BA=FUNAAB Alpha, NB=Nera Black, WL=White Leghorn and GR=Giriraja,

Female genotype

Early wet season

Figures 13, 14, 15 and 16 presented the 20-week growth pattern of female genotypes as predicted by Logistic, Gompertz, Richards and Bertalanffy during the early wet season. Changes in the shape of a growth curve are basically determined by the degree of genetic independence between its parameters (Fitzhugh, 1976). Similar growth patterns were predicted for all the female genotype by the Logistic and Gompertz model with GR and NF having the highest and lowest 20-week body weight respectively by a weight variance of 600g between the genotypes in Logistic and 500g in Gompertz model. The Richards model predicted fairly wide variation between the genotypes than did the Bertalanffy model. In Bertalanffy model, all the genotype did not show much noticeable difference in their growth curve from start to 20th week of growth except GR which had the conspicuous highest weight followed by WL which was a little above other genotypes. In Richards model, GR had the highest weight followed by BA while NF had the lowest. Other genotypes were relatively closer in weight gain.

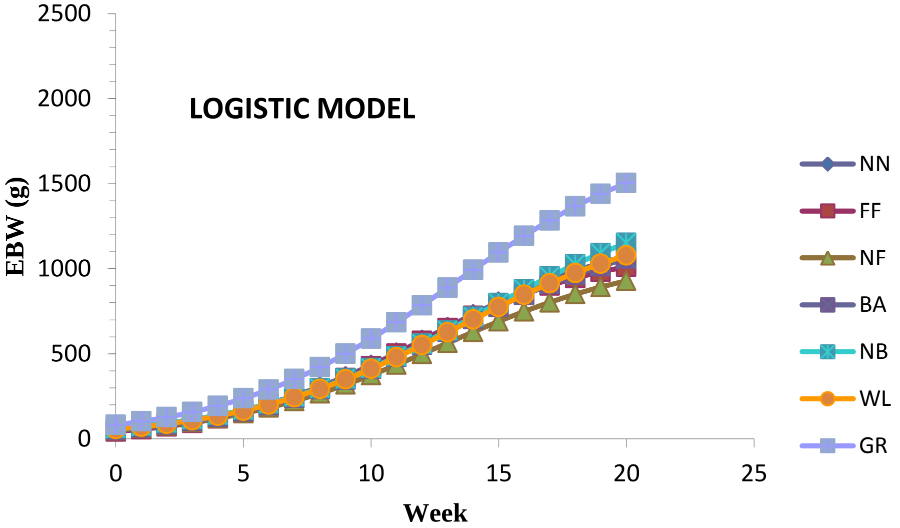

Figure 13. Predicted 20-week growth curves of female chickens reared during early wet season (between April and June)
NN=Naked Neck, FF=Frizzle Feathered, NF=Normal Feathered, BA=FUNAAB Alpha, NB=Nera Black, WL=White Leghorn and GR=Giriraja,

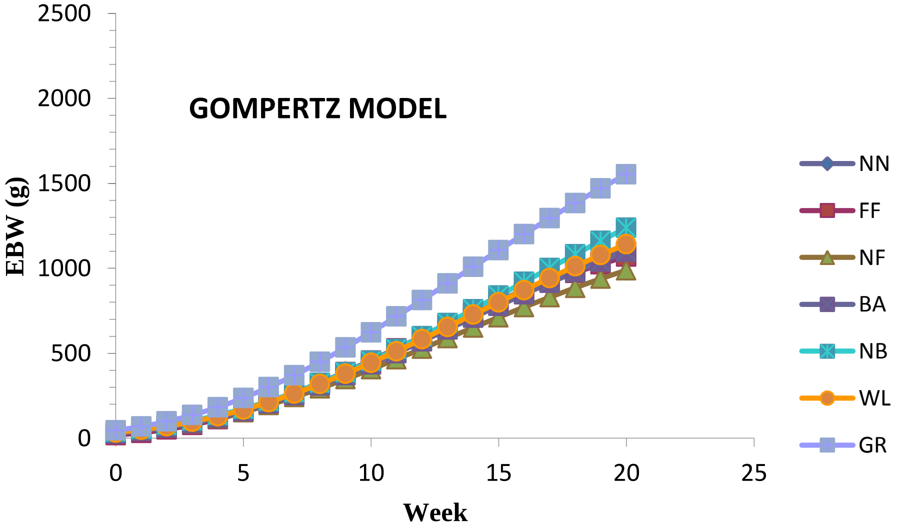

Figure 14. Predicted 20-week growth curves of female chickens reared during early wet season (between April and June)
NN=Naked Neck, FF=Frizzle Feathered, NF=Normal Feathered, BA=FUNAAB Alpha, NB=Nera Black, WL=White Leghorn and GR=Giriraja,

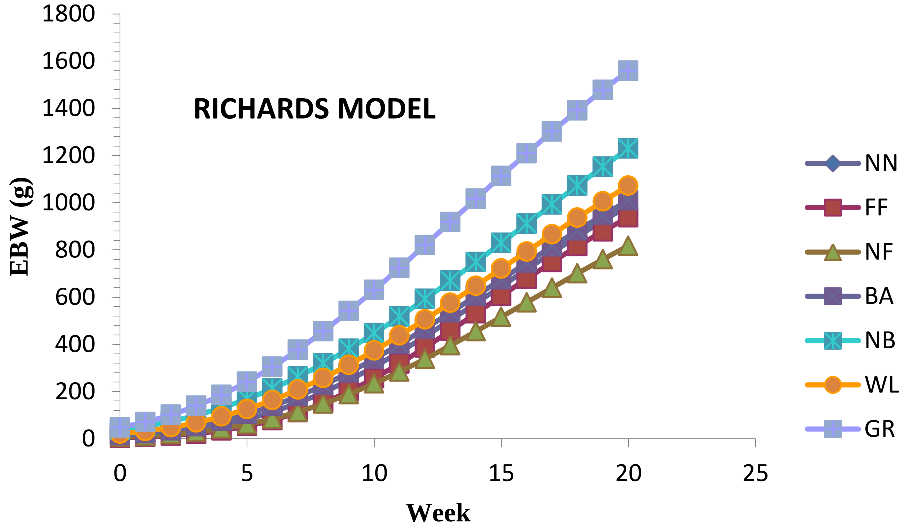

Figure 15. Predicted 20-week growth curves of female chickens reared during early wet season (between April and June)

NN=Naked Neck, FF=Frizzle Feathered, NF=Normal Feathered, BA=FUNAAB Alpha, NB=Nera Black, WL=White Leghorn and GR=Giriraja,

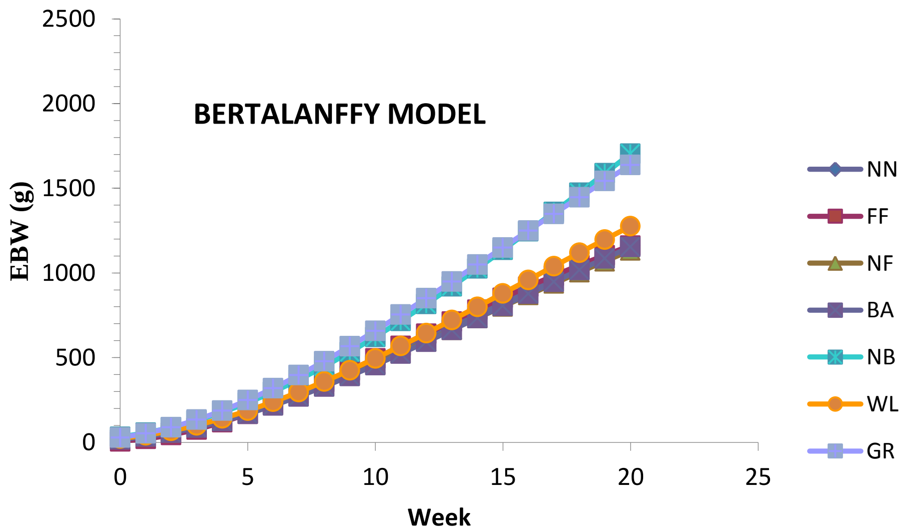

Figure 16. Predicted 20-week growth curves of female chickens reared during early wet season (between April and June)

NN=Naked Neck, FF=Frizzle Feathered, NF=Normal Feathered, BA=FUNAAB Alpha, NB=Nera Black, WL=White Leghorn and GR=Giriraja,

As shown in Table 2, Akaike information criteria (AIC) was used to test the model that best fit the actual data compared to expected or predicted data. The model with the smallest value indicates better fitted model. The result of the best fit model showed that Gompertz model is the best among the model to appropriately fit the growth curve because it had the lowest best fit value for all the genotypes. Similar results was reported by Zhao et al. (2015) and Mohammed (2015) where Gompertz model were more suitable to describe the growth curve in chickens. This could be due to the fact that elements within Gompertz model is best in describing the growth pattern of most poultry birds.

Table 2: Model of best fit

Model	NN	FF	NF	BA	NB	WL	GR
Logistic	11570.50	9060.75	11693.50	6990.00	8185.25	5413.50	7405.00
Gompertz	11451.50	8910.25	11633.00	6810.00	7844.75	5159.50	7245.50
Richards	11458.50	8916.00	11817.50	6904.75	7899.75	5234.50	7391.25
Bertallanfy	11633.00	8924.25	11638.50	6865.50	7946.75	5301.75	7361.75

Conclusion and Recommendation

The growth curves as predicted by the four models gave both male and female GR the highest weight followed by NB at both the late dry and early wet season while the growth curves of WL and NF were lowest at one point or the other. In conclusion, it was observed that the predicted growth curve showed a more consistent output in Logistic and Gompertz model. The goodness of fit favoured Gompertz as the model of best fit for predicting growth curve in both local and locally adapted chickens.

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