Current Journal of Applied Science and Technology

25(5): 1-9, 2017; Article no.CJAST.38994
Previously known as British Journal of Applied Science & Technology
ISSN: 2231-0843, NLM ID: 101664541

Modeling of Body Weight and Component Parts Changes in Broiler Chicken Raised to Maturity

I. M. Sam[1*], C. A. Essien[1] and E. C. Ogundu[1]

[1]Department of Animal Science, Faculty of Agriculture, Akwa-Ibom State University, Akwa-Ibom State, Nigeria.

Authors' contributions

This work was carried out in collaboration between all authors. Author IMS designed the study, performed the statistical analysis, wrote the protocol and wrote the first draft of the manuscript. Authors IMS and CAE managed the analyses of the study. Author ECO managed the literature searches. All authors read and approved the final manuscript.

Article Information

DOI: 10.9734/CJAST/2017/38994
Editor(s):
(1) Ahmed Mohamed El-Waziry, Professor, King Saud University, College of Food and Agriculture Sciences, Kingdom of Saudi Arabia.
Reviewers:
(1) Armagan Hayirli, Ataturk University, Turkey.
(2) Hakan İNCİ, Bingol University, Turkey.
Complete Peer review History: http://www.sciencedomain.org/review-history/22972

Original Research Article

Received 20th November 2017
Accepted 12th January 2018
Published 2nd February 2018

ABSTRACT

The purpose of this study was to model the change in weight and major component parts of broiler chicken using three growth models (Gompertz, Logistics and Richard). A total of two hundred and seventy Abor acre strains of broilers were distributed into two experimental groups of male and female with 135 birds each. The birds were raised on deep litter system for 126 days and weighed individually on weekly basis. Three birds from each group of male and female were dissected bi-weekly to compare growth performance and major component parts using the three nonlinear models. The percent deviation of estimated weight and actual weights were computed. The results showed that Gompertz model gave the least deviation of live body weight and weights of component parts. Logistics and Richard's model underestimated and overestimated live body weights and weights of component part at all phases of growth respectively. Coefficient of determination R^2 (%) recorded for the three growth functions ranged from 93%-98%, giving a good fit for both male and female body weight and component part. Maturation rates (k) were variable but Richard's gave the best estimate of this parameter. The findings in this study suggest that more than one growth model is required to effectively describe the growth of body weight and component parts of broiler chickens.

**Corresponding author: E-mail: sidorenyin@yahoo.com;*

Keywords: Broiler; body weight; component parts; growth functions.

1. INTRODUCTION

In many parts of the world, broiler production offers the most rapid and cost-effective means of making available high-quality animal protein to man. In some areas of the world, poultry meat is prefered over beef because of its higher protein and lower calorie content in addition to other favourable meat qualities such as tenderness [1]. Modern broilers are the result of genetic selection with selection pressure being focused on high growth rate, extensive muscle development and relatively low feed consumption [2,3]. These combine with improved environmental factors such as nutrition and housing have reduced the slaughter age of contemporary broiler chicken to 42 days and slaughter weight above 2 kg [1,4,5]. Consequently, most of the published works on broiler chickens are limited to ages between 42 and 63 days, thus little or no information is available beyond these ages on the growth potential of broiler chicken.

Growth in livestock and poultry in particular is a complex physiological process expressed by changes in body size which exist from conception to maturity [6]. They further explained that analyzing growth usually entails fitting mathematical functions to age-weight data. Growth curves/functions are the most adequate means for describing growth patterns of body weight or body parts because they provide means for visualizing growth pattern over time, and the equations can be used to predict the expected weight of a group of animals at a specific age [3,7,8,9].

Different attempts at mathematically describing the growth of animals have been made over the centuries, the advent of modern computers and the ability to rapidly manipulate complex formulas have made the accuracy and utility of growth models to improve significantly [10]. [11] explain that a good model should not be complex in computation and should be easy for any scientist with basic knowledge of regression to use. The author further stated that the model that is able to make the most accurate prediction when compared to the actual is very reliable and is a great asset to both the farmer and the breeder.

Several growth functions are available for description of growth such as Richards, Gompertz, Logistics, Von Bertallanfy, France, Lopez, monomolecular functions etc [12]. In Nigeria, there are few published studies on broiler chicken raised to maturity; therefore the aim of this study was to model the changes in weight and component parts of broiler chicken raised to maturity using three non-linear growth models.

2. MATERIALS AND METHODS

2.1 Study Area

The study was conducted at the Poultry Unit of the Animal Science Department, Ahmadu Bello University, Samaru –Zaria, located within the Northern Guinea Savannah zone of Nigeria (Latitude 11°12'N and Longitude 7°33'E) at an altitude of 610 m above sea level [12]. The climate is relatively dry, with mean annual rainfall ranging from 700 to 1400 mm and occurring between the months of April and September. The dry season begins around the middle of October, with cold weather that ends in February. This is followed by relatively hot, dry weather from March to sometime in April, when the rains begin. The mean minimum and maximum daily temperatures are 14°C and 24°C respectively during cool season and 19°C and 36°C, respectively during the hot season. Relative humidity varies between 19 and 35% in the dry season, and between 63 and 80% in the rainy season.

2.2 Experimental Birds

Two hundred and seventy (270) Abor Acre broiler strains were purchased from a commercial hatchery. The birds were separated into two groups of males and females, birds were leg banded for individual identification and were raised on deep litter system.

2.3 Feeding Management

The birds were uniformly supplied with feed and water *ad libitum*. Starter ration (24% CP and 3000 kcal ME/Kg) was fed to the birds from day old to four weeks of age. They were also fed commercial broiler finisher (20%CP and 2950 Kcal ME/kg) from the 5th week to 18th weeks of age. The laboratory analysis of the experimental diet is shown in Table 1.

2.4 Slaughter and Dissection Procedures

Three birds from each group of male and female were selected for slaughter every two weeks. The birds were slaughter by cutting through the neck with a sharp knife. The feathers were removed after immersion in hot water at 65°c for one minute. The carcasses were cut into parts (Back, Breast, and Thigh).

2.5 Data Collection

Data on body weight was collected weekly and weights of component parts were obtained bi-weekly.

2.6 Modeling of Growth

Gompertz, Logistics and Richard functions were used to fit data of live weight and weight of major carcass component parts. The growth functions used were as follows

Richard

$$W = (W_0W_f/[W_0^n + (W_f^n - W_0^n)\exp(-bt)]^{1/n}$$

Logistic

$$W = W_oW_f/\{W_o + (W_f - W_o)\exp(-bt)\}$$

Gompertz

$$W = W_o\exp\{(1-\exp(-bt)\}\ln(W_f/W_o)\}$$

Where, W = live weight(g); t = time(days); W_f = final weight(g); W_o= initial weight(g); b and n are constant

SAS [13] non- linear procedure was used to fit the functions.

Suitability of the models was assessed using the general goodness of fit (R^2), predictive ability and t-test between the actual values and predicted values.

3. RESULTS AND DISCUSSION

The actual and estimated body weight of male and female broilers using Gompertz, logistic and Richard's growth model are shown in Table 2. The results indicated that the estimated body weight of male and female broilers using the Gompertz growth model was very close to the actual, percent difference between the estimated live body weights and the actual live weight was 2.60% and 2.91% (Table 3) respectively. The growth curves for live body weight in males and females are shown in Figs. 1 & 2. Maturation rate was highest in Richards model (0.0317 and 0.0291) for males and females respectively), time at the point of inflection was at 49 and 56 days in males and females respectively (Table 2). This report is similar to reports of [3] who recorded 0.036 as a rate of maturing for cobb 500 and shaver starbro male broilers. [14,15] were also led to similar conclusions. The reports from this work are contrary to the work of [16] who reported that maturation rates for crossbred chickens were -0.13, 119591.44 and -0.22 for monomolecular, Richards and Gompertz function respectively. The differences may probably be due to differences in the breed used and the ages of the birds.

Table 1. Energy and proximate composition of the two rations used

	Starter ration	Finisher ration
Metabolizable energy (kcal/kg)	3200	2950
Crude protein (%)	23.2	20.13
Dry matter (%)	90.0	91.17
Crude fibre (%DM)	7.5	7.58
Ether extract (%DM)	6.5	5.49
Ash(%DM)	7.63	9.48
Nitrogen-free extract (%DM)	60.32	57.32

The actual and estimated weights of the back using the three growth models indicated that males were heavier than females (Table 2). Gompertz model estimated the back weight very close to actual than logistic and Richard model. The percentage deviation of the estimated weight of the back and the actual were 2.81% and 2.80%; 15.96% and 15.57%; -324.41 and -324.55 for males and females using Gompertz logistics and Richard growth models respectively. The growth curves showed that Gompertz model underestimated the weight of the back from the beginning, but was similar to the actual weight from the twelfth week. The growth curves also showed that logistics model underestimated the weight of the back from week one to eighteen while Richards's model overestimated the weight from week one to eighteen. The rate of maturing was highest using the Richard model.

Table 2. Estimated parameters of Gompertz, Logistics and Richard's equation of live weight, back, breast and thigh weight of males and females broilers

	Growth functions					
Parameter	**GOMPERTZ**		**LOGISTICS**		**RICHARD**	
Body Wt	**M**	**F**	**M**	**F**	**M**	**F**
Act Wt(g)	1900	966.7	1900	966.7	1900	966.7
W^*(g)	1851.21	1947.8	1446.72	1756.93	5114.18	1947.8
B (constant)	-420.8	-260.56	-583.14	-399.24	-187.94	-132.38
K(by day)	0.010	0.099	0.097	0.089	0.3171	0.291
T(day)	49	56	49	56	49	56
R^2	97	97	95	95	96	97
Back Wt						
Act Wt(g)	316.3	177.8	316.3	177.8	316.3	177.8
W^*(g)	307.58	166.54	222.82	108.88	1300.05	683.77
B (constant)	-59.62	-41.12	-86.86	-62.98	-324.93	-234.61
K(by day)	0.010	0.099	0.097	0.087	0.451	0.432
T(days)	36	49	36	49	36	49
R^2	98	97	95	97	97	98
Breast Wt						
Act Wt(g)	292.7	204.7	292.70	204.7	292.7	204.7
W^*(g)	283.8	189.46	147.88	71.67	748.28	484.2
B (constant)	-58.71	-73.18	-107.65	93.59	-226.08	-185.53
K(by day)	0.099	0.010	0.093	0.070	0.279	0.268
T(days)	36	49	36	49	36	49
R^2	96	98	96	93	96	97
Thigh Wt						
Act Wt(g)	462.8	262.4	462.8	262.4	462.8	262.4
W^*(g)	489.51	244.04	286.22	135.06	1877.58	987.43
B (constant)	101.49	-46.94	-149.67	84.58	-544.96	-278.94
K(by day)	0.010	0.099	0.095	0.086	0.451	0.430
T(days)	36	49	36	49	36	49
R^2	97	97	93	95	96	96

t^*=time at point of inflection, W^*= Estimated weight, R^2=Coefficient of determination, b- constant, k= rate of maturing

Table 3. Comparison between actual and estimated live weight and major component parts of broiler using Gompertz, Logistics and Richard's growth model

Parameters	**Male**			**Female**		
	Actual	**Estimated**	**%D**	**Actual**	**Estimated**	**%D**
Gompertz						
LW	1732.8	1687.71	2.60	1671	1622.17	2.91
BACK	256.82	249.59	2.81	261.48	253.9	2.80
BREAST	256.54	249.81	2.62	264.97	257.25	2.91
THIGH	396.62	382.22	3.63	386.76	375.44	2.93
Logistics						
LW	1732.8	1493.72	13.79	1671	1435.15	14.12
BACK	256.82	215.82	15.96	261.48	220.79	15.57
BREAST	256.54	189.33	26.19	264.97	195.27	26.30
THIGH	396.62	313.94	20.84	386.76	309.43	19.94
Richard						
LW	1732.8	49905.6	-2780.5	1671	47850.9	-2763.55
BACK	256.82	1089.99	-324.41	261.48	1110.13	-324.55
BREAST	256.54	680.94	-165.43	264.97	701.04	-164.55
THIGH	396.62	1663.56	-319.43	386.76	1635.75	-322.91

%D= Percent Deviation

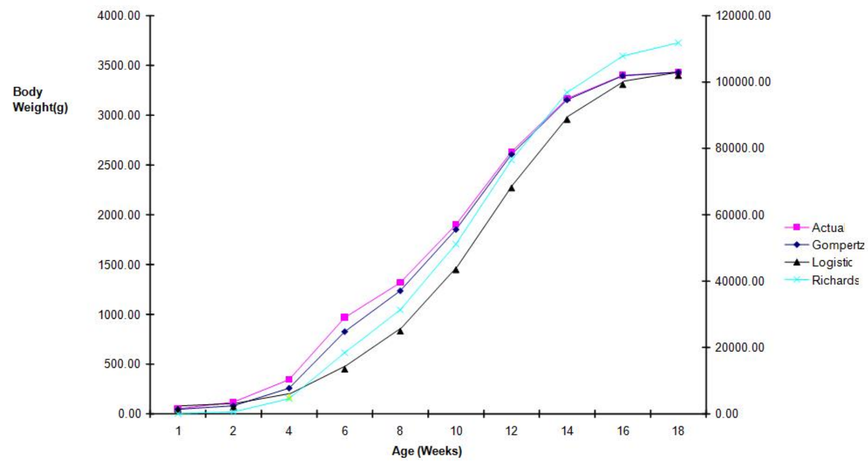

Fig. 1. Actual and predicted growth curves for body weight males using the three growth models

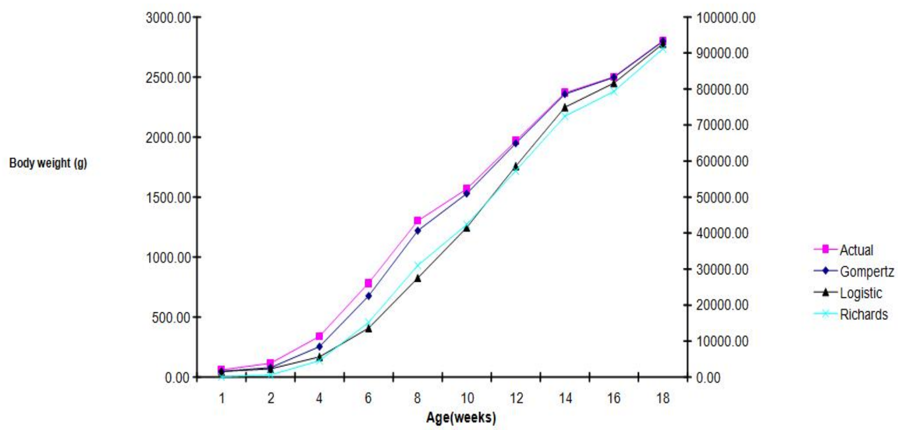

Fig. 2. Actual and predicted growth curve for body weight in females using three growth models

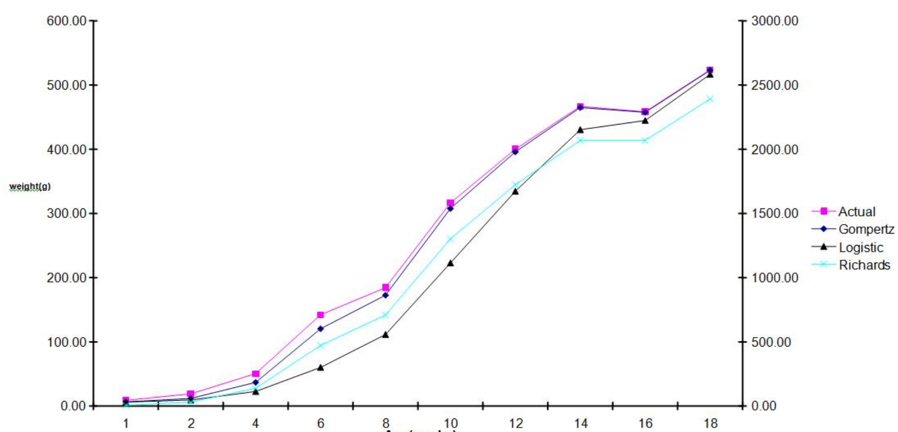

Fig. 3. Actual and predicted growth curve for back weight in males using three growth models

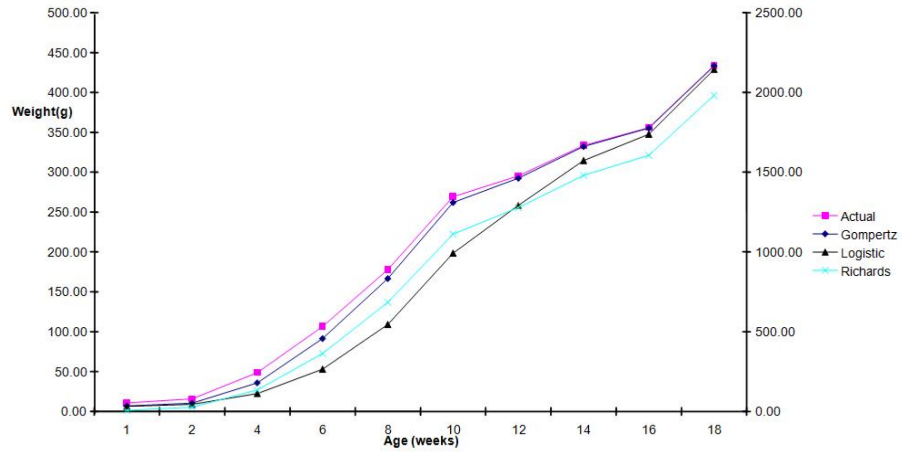

Fig. 4. Actual and predicted growth curve for back weight in female using three growth models

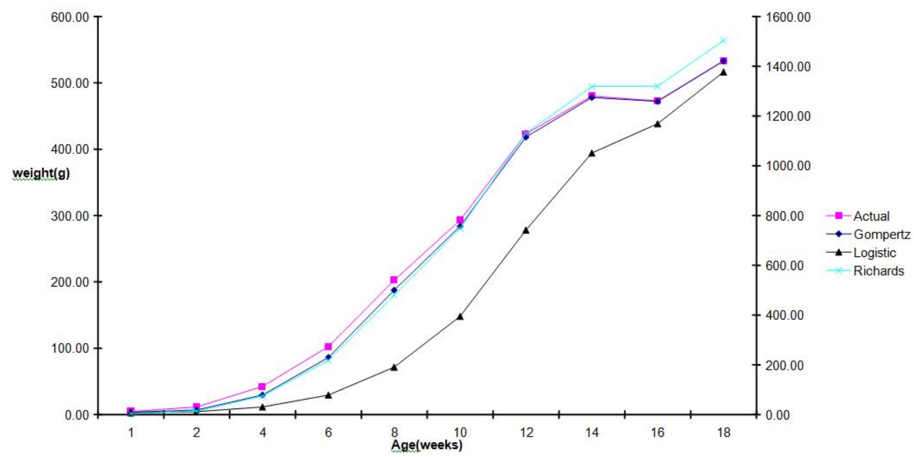

Fig. 5. Actual and predicted growth curve for breast weight in male using three growth models

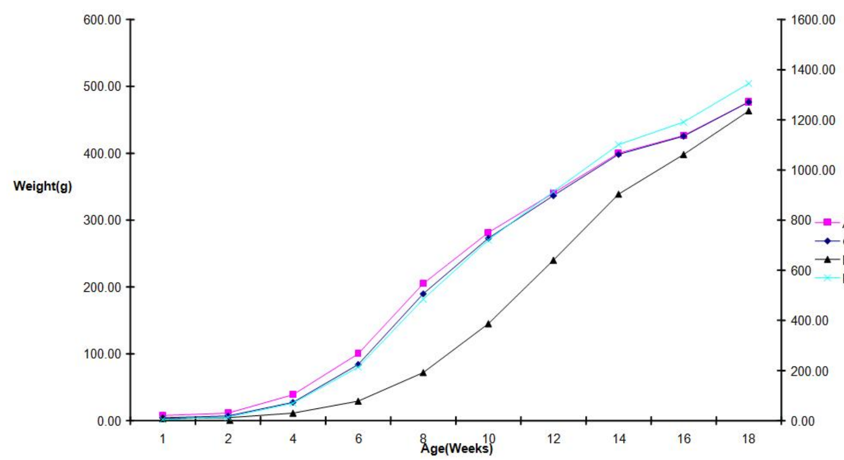

Fig. 6. Actual and predicted growth curve for breast weight in separated females using three growth models

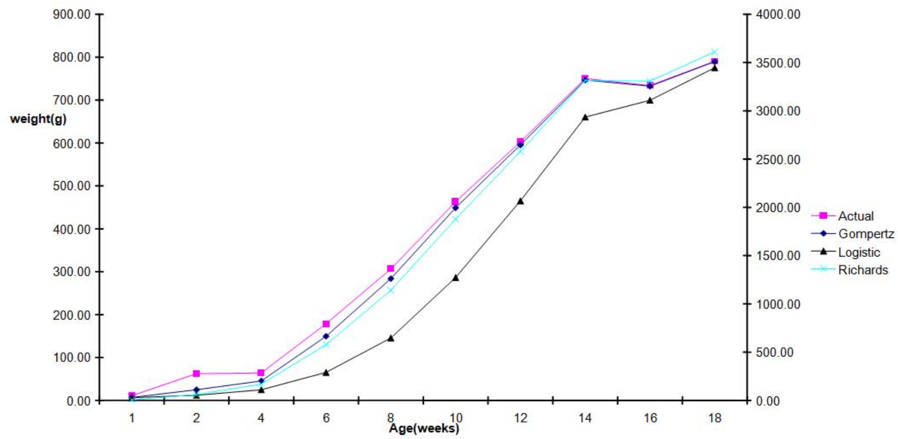

Fig. 7. Actual and predicted growth curve for thigh weight in separated male using three growth models

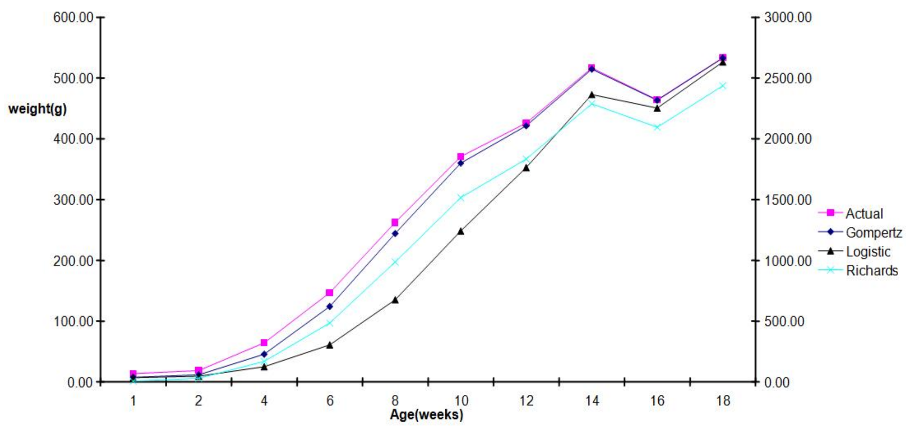

Fig. 8. Actual and predicted growth curve for thigh weight in female using three growth models

The breast mature weights of males were higher than the females and were 283.8 and 189.46, 147.88 and 71.67, 748.28 and 484.2 for males and females using Gompertz, logistic and Richard respectively (Table 2). [17] reported mature breast weight of cobb and ross strain of broiler chicken to be 1868.20 g and 1518.20 g for male and female Ross strain respectively and 1908.80 and 1233.70 g for male and female cobb strain respectively. Richard model gave a greater rate of maturity (k) 0.0317 and 0.0291 for males and females respectively. The time at the point of inflection in this study for the breast was 42 and 49 days for males and females respectively in all the models used. [3] observed mature breast weight of 1744.2 g and the time at the point of inflection to be 47 days.

The mature weights of the thighs were 462.8 g and 262.4 g, 462.8 g and 262.4 g, 462.8 g and 262.6 g for males and females using Gompertz, logistics and Richard functions respectively. The thigh weight using the three growth model showed that Gompetz model estimated the weight to be very close to the actual weight with percentage deviation of 3.63% in males and 2.93% in females (Table 3). The rate of maturity of the thigh (Table 2) was higher in both male and female when Richards's model was used. The logistics and Richard's model underestimated and overestimated the weight of the thigh respectively. The growth curve for weight of thigh in males and females broilers using the three growth models are shown in Figs. 7 & 8, the curves showed that Gompertz model estimated the weight of broiler's thigh to be very close to the actual from week one to the twelfth week and became similar to the actual weight at week twelve and eighteen. Logistics and Richard model underestimated and overestimated weight of thigh at all ages respectively. The time at the point of inflection of the thigh was reached at 42 and 49 days for all the growth model used, this was higher than the reports of [17] who reported 37 and 41 days for ross and 39 and 46 days for cobb, females and males respectively.

All three growth model used fitted well the age-weight data of broiler birds, as they all had high R^2 value (coefficient of determination). Coefficient of determination measures the amount of variability accounted for by the fitted model [11] and R^2 values of 70% and above indicate good measure of fitness as explained by [18].

Gompertz's model gave the best fit in terms of estimation of body weight and parts, [3,16] were led to similar conclusions. However, this is contrary to the work of [19,20,21] who found that Richards' function gave better estimates of body weights of broilers. However, Richard's model had the best estimate of maturation index (K). [14] explained that the higher the value of maturation index, the earlier the birds mature. [16] in their study also observed that Richard's function gave a better estimate for maturation rate.

Estimated live body weight and weights of a component part of broiler chicken in this work (body weight, back, breast and thigh) were lower than those presented by [3,17] probably due to differences in the breed used, management and environmental condition. Although Gompertz's model estimated growth in terms of live weights and component parts of broiler birds at various ages well (very close to actual), but it had some limitations in estimating the rate of maturity of body weight and component parts. Richard's function though overestimated body weight and that of component parts was better than Gompertzs and Logistics in estimation of the rate of maturity of body weight and weights of component parts. Therefore, none of these models is complete in itself to wholly estimate growth in broiler chickens. It requires a combination of two or more models. These findings agrees with the report of [16], who concluded that more than one growth model is required to efficiently describe growth curves/pattern of various chicken breeds.

4. CONCLUSION

The pattern of growth of broiler chickens was adequately described by all three models except Richard's, which overestimated live body weight and weights of component parts, the best fit was provided by Gompertz model which accounted for the least percent deviation from the actual weights. However, maturation rate was best described by Richard's model. Therefore, the findings in this study suggest that more than one growth model is required to effectively describe the growth of live body weight and weights of component parts in broiler chickens.

ETHICAL APPROVAL

As per international standard or university standard, ethical approval has been collected and preserved by the authors.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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Peer-review history:
The peer review history for this paper can be accessed here:
http://www.sciencedomain.org/review-history/22972