Growth characteristics of noiler chickens as determined by nonlinear algorithms

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Abstract

The assessment of growth characteristics of noilers chickens as determined by non-linear algorithms will provide the best mathematical function in the growth of male and female noilers chickens. This study sought to determine the adequacy of two mathematical functions for modeling growth characteristics of male and female Noiler® chickens. Body weights and morphometric traits of 200 Noiler chickens were measured bimonthly for 20 weeks and the data obtained fitted to the Gompertz and Logistic growth models using the nonlinear regression. The results showed significant ($P < 0.05$) difference between males and females only at 16, 18 and 20 weeks of age, with values of 2316.2 vs 2121.9 g, 2624.3 vs 2378.1 g, and 3002.7 vs 2718.7g, respectively. There were no discernable differences between males and females for most body measurements except body length which was longer in the latter than former from 14 weeks of age. The asymptomatic weight (A) of the models revealed that Gompertz model had higher values for both male and female Noilers than the Logistic for body weight and all morphometric traits. The reverse was observed with the scale parameter (B) and relative growth rate (C) for all traits. The coefficient of determination (R^2) values for both models (male and female) were generally high ($> 80\%$) indicating a good fit for the data. The other goodness of fit criteria; Akaike Information Criterion (AIC) and standard deviation (SD) were lower for the Gompertz compared to Logistic for both male and female. Thus, the study revealed that the Gompertz was the better model for explaining the growth patterns of both male and female Noiler chickens.

Keywords: Models, noiler, body weight, Morphometric traits

Caractéristiques de croissance des poulets noilers déterminés par des algorithmes non linéaires

Résumé

L'évaluation des caractéristiques de croissance des poulets de Noilers tels que déterminées par des algorithmes non linéaires fournira la meilleure fonction mathématique de la croissance des poulets de Noilers masculins et féminins. Cette étude a cherché à déterminer l'adéquation de deux fonctions mathématiques pour la modélisation des caractéristiques de croissance des poulets mâles et femelles Noiler. Les poids corporels et les traits morphométriques de 200 poulets nilaques ont été mesurés bimenshly pendant 20 semaines et les données obtenues dans les modèles de Gompertz et croissance logistiques utilisant la régression non linéaire. Les résultats ont montré une différence significative ($p < 0,05$) entre les mâles et les femmes seulement à 16, 18 et 20 semaines, avec des valeurs de 2316,2 vs 2121,9 g, 2624,3 contre 2378,1 g et 3002,7 vs 2718,7g, respectivement. Il n'y avait pas de différences discernables entre les hommes et les femmes pour la plupart des mesures du corps, à l'exception de la longueur du corps, ce qui était plus long que l'ancien de 14 semaines. Le poids asymptotique (A) des modèles a révélé que le modèle de Gompertz avait des valeurs plus élevées pour les noilers mâles et femelles que la logistique pour le poids corporel et tous les traits morphométriques. L'inverse a été observé avec le paramètre d'échelle (B) et le taux de croissance relative (C) pour tous les traits. Le coefficient de valeurs

de détermination (R^2) pour les deux modèles (hommes et femmes) était généralement élevé (> 80%) indiquant un bon ajustement pour les données. L'autre bonté des critères d'ajustement; Le critère d'information Akaike (CIA) et l'écart type (ET) étaient plus bas pour le Gompertz par rapport à la logistique pour les hommes et les femmes. Ainsi, l'étude a révélé que le Gompertz était le meilleur modèle d'explication des schémas de croissance des poulets mâles et femelles Noilers.

Mots-clés: Modèles, noiler, poids corporel, sexe, morphométrie, traits

Introduction

Poultry production is one of the best means for production of high biological value animal protein in terms of eggs and meat (Yakubu *et al.*, 2007). The poultry sector contributes about 25% of the agricultural domestic products of the Nigerian economy (FAO, 2010). Nigeria presently produces above 550,000 mt of poultry meat per annum and 770,000 mt of eggs (FAO, 2010). Poultry meat and eggs account for about 30% of total livestock output in Nigeria, of which eggs account for over 80 percent (Fayeye *et al.*, 2005). Ogundipe and Sanni (2002) reported that poultry production plays an important role in contributing to income as well as nutritional status of the country. Mathematical functions called growth models (each with a non-linear structure and sigmoid shape) have been used to explain the growth patterns of poultry species (Narine *et al.*, 2017). The main advantage of nonlinear models is parsimony, interpretability and prediction (Bates and Watts, 2007). Growth curve parameters are highly heritable and have been widely exploited in poultry selection studies (Magainon-Grasteav, 2001). Studies had been carried out for the prediction of future growth at any age in poultry (Raji *et al.*, 2014). Feeding regimens can be determined using mathematical model in addition to the nutritional requirements at various growth stages (Selvaggi *et al.*, 2015). The Noiler is a dual purpose breed of chicken developed by Amo farm Sieberer Hatchery Limited for small holders to address the challenges of food insecurity and financial dependency

among rural populace especially women. It has been emphasized that the introduction of tropically adapted genotypes with high performance is beneficial to the resource poor poultry farmers (Yakubu and Ari, 2018). Knowledge of growth of Noiler birds is important to evaluate their development at all ages. Thus, the objective of this study was to determine the effect of sex on body weight and morphometric traits as well as the appropriate model for describing growth of Noiler chickens.

Materials and methods

Experimental animal and management

A total of 200 day old Noiler chicks were obtained from a reputable hatchery. The birds were brooded for three weeks on wood shavings using coal pots to supply heat, after which they were placed under deep litter management system for 140 days (20 weeks). All the birds were tagged individually for proper identification. They were fed with a commercial chick mash (1-8 weeks) containing 3000 kcal/kg of energy and 20% Crude protein (CP) and grower mash (8 – 20 weeks) containing 2650Kcal/kg of energy and 16% crude protein (CP). Clean water and feed were given ad libitum and routine vaccination and other management practices were strictly adhered to.

Data collection and models

The body weight and morphometric traits were measured for each bird once every two weeks for the duration of the experiment thus:

Body weight: This was taken using a weighing balance calibrated in grams (g).

Body Length: This was measured as distance between the base of the neck to the tailend.

Shank Length: This was measured as the length of the tarso-metatarsus from the hock joint.

Thigh length: This was measured as distance between the hock joints and pelvic joints.

Wing length: This was measured from the tip of the right wing to the tip of the left wing.

Chest girth: This was measured as the circumference of the breast around the deepest region of the breast.

All the data collected were fitted into the following growth models

1. Logistic model's: the following equation describes the Logistics (Roberison,1923) growth model

$$W_t = W_a / [1 + \exp -K(t-T_i)]$$

where:

W_t = the body weight at time t ,

W_a = asymptotic body weight,

K = the exponential growth rate, and T_i the age at the inflection point.

2. Gompertz–Laird model: the laird form of the Gompertz equation (Laird *et al.*,1965) was fitted to the data. The following equation describes the Gompertz-Laird growth curve;

$$W_t = W_o \exp [(L/K) (1 - \exp -Kt)]$$

Where:

W_t = weight of bird at time t ,

W_o = initial body (hatch) weight,

K = rate of exponential decay of the initial specific growth rate,

Data analysis

The data generated from body weight and morphometric measurements were subjected to Analysis of variance using Statistic 9.0. Significant means were compared by Least Significant Difference. The models were fitted to the chicken growth data using Levenberg- Marquardt nonlinear least-squares algorithm in Statistic 9.0 and curve parameters obtained.

Determination of goodness of fit

The asymptotic body weight (A), Akaike's information Criterion (AIC), Standard Deviation (SD) and Coefficient of Determination (R^2) were used for model comparison. Goodness of fit for each model was determined by using the coefficient of determination (R^2) and Akaike's Information Criterion (AIC) and Standard Deviation (SD).

Results and discussion

The effects of sex on body weight and morphometric traits of Noiler chickens at different ages are presented in Tables 1 and 2. The results showed that sex had significant ($p < 0.05$) influence on body weights at 16, 18 and 20 weeks of age. At these ages, the males had superior body weight (2316.2, 2624.3 and 3002.7 g, respectively) compared to the females (2121.9, 2378.1 and 2718.7 g). Similarly, body length differed significantly with sex at the later stages of growth (14, 16, 18 and 20 weeks of age). The corresponding values for male and female, respectively at these ages were 54.39 vs 36.73 g, 63.78 vs 40.59 g, 71.94 vs 42.30 g and 80.69 vs 42.64 g. However, sex did not significantly affect the other morphometric traits of Noiler chickens. This result indicated that the difference in weight and body length between male and female Noiler was only obvious at the later stages of growth. The superiority of males over females for body weight agrees with the findings of Kesheri *et al.* (1985) and Rondeli *et al.* (2003). These authors reported that males were heavier than females during the growing stage. The results of this study was in contrast to that of Al-Qamashoui *et al.* (2014) who reported significantly higher values for shank length for males (8.1 cm) compared to females (7.1 cm). Okpeku *et al.* (2003) also showed that shank length was higher in males (9.52 cm) than females (8.99 cm) for local chickens in Edo state.

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The reported differences may be as a result of the diverse genotypes used in the studies. Males were generally bigger and heavier than the females in this study probably due to the effect of hormonal differential on growth, which promotes greater skeletal and tissue growth in males compared to females. It has also been reported that sex difference in weight was usually due to difference in hormonal profiles, aggressiveness and dominance especially when both sex are reared together (Ibe and Nwosu, 1999). The results of wing length chest, girth, and chest weight showed no significant difference ($p<0.05$) between

males and females at all stages of growth. This agrees with the findings of Okpeku *et al.* (2003) who studied several breeds of chickens and reported that there were no significant differences in chest weight (CW), Thigh length (TL) and wing length (WL) for both sexes. Apuno *et al.* (2011) also reported that breast girth was not affected by sex.

Both male and female Noiler chickens were 3.4 and 3.94% matured at 2 weeks of age. The birds were 70 and 76% matured at 14 weeks and 87% at 18 weeks. Though, females matured faster than males, the latter had higher matured weight.

Table 1: Means (g) and degree of maturity (DMAT%) of body weight of male and female Noiler chickens at different ages

Age (weeks)	Sex		DMAT (%)	
	Male	Female	Male	Female
2	102.05±5.55	107.22±4.22	3.40	3.94
4	252.73±13.72	252.73±10.43	8.42	9.30
6	414.51±26.08	409.97±10.83	13.80	15.08
8	865.31±30.02	821.26±33.23	28.82	30.21
10	1129.39±43.21	1081.24±41.11	37.61	39.77
12	1686.50±90.41	1600±68.74	56.17	58.85
14	2095.70±220	2076.6±167.7	69.79	76.38
16	2316.20±103.2 ^a	2121.9±77.81 ^b	77.14	78.05
18	2624.30±104.3 ^a	2378.1±79.27 ^b	87.40	87.47
20	3002.70±111.8 ^a	2718.7±84.99 ^b	100.00	100.00

^{a,b}Means in a subset within the same row bearing different superscripts are significantly different ($P<0.05$)
DMAT= degree of maturity

Table 2. Effect of sex on morphometric traits of Noiler chickens at different ages

Age (weeks)	Sex	BL (cm)	TL (cm)	SL (cm)	WL (cm)	CG (cm)	CW (cm)
2	Male	14.54±1.20	3.40±0.15	6.16±0.15	7.46±0.20	12.15±0.26	3.86±0.06
	Female	12.56±0.91	3.58±0.08	6.00±0.11	7.35±0.16	12.19±0.20	3.80±0.05
4	Male	20.14±2.41	7.35±0.12	8.22±0.13	12.01±0.15	16.77±0.27	5.22±0.07
	Female	16.39±1.81	7.17±0.09	8.13±0.13	12.01±0.17	16.77±0.27	5.22±0.06
6	Male	24.31±4.41	8.62±0.23	10.05±0.24	14.75±0.33	21.22±0.54	5.90±0.12
	Female	20.22±4.91	8.62±0.23	9.69±0.19	14.62±0.25	21.22±0.54	5.90±0.12
8	Male	27.56±4.43	10.70±0.43	12.53±0.23	21.50±0.23	28.60±0.78	7.94±0.12
	Female	23.18±6.93	9.95±0.33	11.96±0.20	21.71±0.23	27.20±0.72	7.53±0.12
10	Male	31.23±6.45	12.50±0.13	12.99±0.25	34.77±0.33	32.62±0.82	9.90±0.26
	Female	26.96±4.93	11.73±0.17	12.06±0.20	34.10±0.25	32.46±0.71	9.54±0.21
12	Male	34.77±2.15	14.20±0.27	14.74±0.26	42.08±1.16	37.51±0.95	10.85±0.31
	Female	34.77±2.65	13.68±0.20	14.33±0.20	43.78±0.88	37.28±0.72	11.09±0.24
14	Male	54.39±8.40 ^a	14.76±0.23	15.78±0.26	50.02±0.86	42.21±0.99	10.49±0.21
	Female	36.73±3.73 ^b	14.40±0.17	15.45±0.20	49.24±0.65	41.38±0.75	10.34±0.16
16	Male	63.78±3.94 ^a	15.67±0.24	17.00±0.28	52.74±0.82	42.87±1.01	11.89±0.22
	Female	40.59±4.29 ^b	15.00±0.18	16.23±0.21	52.00±0.62	41.03±0.76	11.78±0.16
18	Male	71.94±4.68 ^a	15.90±0.27	17.06±0.29	55.08±1.03	44.75±1.07	13.28±0.25
	Female	42.30±3.69 ^b	15.93±0.21	16.68±0.22	55.08±1.02	43.92±0.81	13.32±0.19
20	Male	80.69±7.95 ^a	16.51±0.26	17.30±0.27	55.52±0.90	46.25±0.99	14.71±0.26
	Female	42.64±4.06 ^b	16.06±0.20	16.84±0.21	54.25±0.68	43.92±0.75	14.47±0.20

^{a,b}Means in a subset within the same column bearing different superscripts are significantly different ($P<0.05$), BL= Body length, TL= thigh length, SL= shank length, WL, Wing length, CG=Chest girth and CW =chest weight

Estimated coefficients for all models and the goodness of fit criteria of body weight and morphometric traits of male Noiler chickens are presented in Table 2. All models had considerably high coefficients of determination (R^2) values (0.81 – 0.93) for body weight and morphometric traits of male Noilers. This indicates that the growth curves of the observed data were adequately described by the models for all traits. The asymptotic weight (A) for all the traits were higher for the Gompertz than Logistic model while the reverse was the case for the scale parameter (B) and relative growth rate (C). Thus, for all traits, the Gompertz had higher asymptotic weight but lower scale parameter and relative growth rate. The asymptotic weight for body weight of male Noilers as determined by the Gompertz model is 3891.90 g with B and C values of

1.58 and 0.13, respectively. The corresponding values for the Logistic models were 3133.60 g, 3.55 and 0.29. The model with a better fit can be determined from the values of the goodness of fit criteria; coefficients of determination (R^2), standard deviation and Akaike information criterion (AIC), usually, the best model is one with higher coefficient of determination (R^2) and lower Akaike information criterion (AIC) and standard deviation. The R^2 , AIC and SD of the Gompertz for body weight were 0.812, 6927.50 and 511.01 with corresponding values of 0.810, 6933 and 513.55 for the Logistic. A similar trend was observed for all morphometric traits. Thus, the Gompertz model consistently had higher R^2 and lower AIC and SD for all traits compared to the Logistic.

Table 3: Model parameters and goodness of fit criteria for different growth models fitted to the body weight and morphometric traits of male noiler chickens

Trait	parameter	A	B	C	AIC	R^2	SD
BW	Gompertz	3891.9	1.5858	0.1396	6927.5	0.8122	511.01
	Logistic	3133.6	3.5544	0.2900	6933.0	0.8103	513.55
BL	Gompertz	50.528	0.6701	0.1322	1395.3	0.9290	3.4991
	Logistic	46.854	1.7775	0.2055	1412.6	0.9267	3.5538
TL	Gompertz	16.260		0.8567	0.2406	446.00	0.9161 1.4888
	Logistic	15.810	1.7775	0.3497	488.08	0.9085	1.5464
SL	Gompertz	17.826	0.5635	0.1957	521.24	0.8966	1.5921
	Logistic	17.301	1.2849	0.2732	540.07	0.8989	1.6193
WL	Gompertz	62.341	1.2918	0.1856	1852.9	0.9373	5.2843
	Logistic	57.524	2.7418	0.3146	1822.0	0.9407	5.1391
CG	Gompertz	49.733	0.7649	0.1660	1571.0	0.9201	40989
	Logistic	46.980	1.6683	0.2527	1580.7	0.9187	4.1349
CW	Gompertz	27.316	0.7744	0.0604	476.92	0.897	1.2786
	Logistic	20.298	1.6275	0.1246	493.73	0.8953	1.2898

A =Asymptomatic weight B =Scale parameter (contsant), C =Relative growth rate, AIC =Akaike's formation criteria, R2 =coefficient of deternination, SD =standard deviation, BW =body weight, BL =body length, TL=Thigh length, SL=Shank length, WL=Wing length, CG=Chest girth, and CW=Chest width.

Model parameters and goodness of fit criteria for different growth models fitted to the body weight and morphometric traits of female Noiler chickens are shown in Table 3. The coefficient of determination for body weight and morphometric traits of female Noiler chickens were generally high (0.67 –

0.94). This implies that the models adequately fit the observed body weight and morphometric traits data of the chickens. The Gompertz model had consistently higher R^2 than Logistic for most traits except tail length where the reverse was the case. As was observed for male Noiler

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chickens, the Gompertz model had higher asymptote values and lower scale parameter and relative growth rate compared to the Logistic for all the traits studied in their female counterparts. The asymptote value for body weight as estimated by the Gompertz model was 3365.9 g compared to 2817.2 g for the Logistic. A similar trend was observed for all the morphometric traits. The Gompertz model also had lower scale parameter and relative growth rate than the Logistics for

all traits. Similarly, the values of Akaike Information Criteria (AIC) and Standard deviation were lower for the Gompertz model compared to the Logistic for all traits. Thus, the Gompertz model had higher R^2 and lower AIC and SD than the Logistic. This implies that the Gompertz describes the growth curve of the female Noiler chickens better than the Logistic. Masoudi and Azarfa (2017) stated that the best model is that with a higher coefficient of determination R^2 and lower Akaike information Criterion (AIC).

Table 4: Model Parameters and Goodness of fit criteria for different growth models fitted to the Body weight and Morphometric trait of female Noiler chicken

Trait	Parameter	A	B	C	AIC	R^2	SD
BW	Gompertz	3365.9	1.5832	0.1518	12319	0.7250	610.12
	Logistic	2817.2	4.5081	0.3021	12325	0.7233	611.97
BL	Gompertz	46.673	0.6541	0.1529	3294.7	0.8298	5.5475
	Logistic	44.228	1.645.7	0.2270	3307.3	0.8298	5.5842
TL	Gompertz	16.140	0.7949	0.2208	3289.2	0.8276	5.5475
	Logistic	15.672	1.6574	0.3145	720.86	0.9144	1.4518
SL	Gompertz		16.934		0.5521	0.2152	2161.1 0.6744 0.6744
	Logistic		16.525	1.2561	0.2964	2172.9	0.6704 3.0965
WL	Gompertz	60.260	1.3192	0.1973	3058.7	0.9442	49059
	Logistic		56.120	2.7783	0.3302	2979.5	0.9437 4.7076
CG	Gompertz	47.692	0.7718	0.1784	2649.0	0.9212	3.9633
	Logistic		45.325	1.6799	0.2699	2654.5	0.9208 39746
CW	Gompertz		27.316		0.1744	0.0604	476.92 08971 1.2786
	Logistic		20.298	1.6275	0.1246	493.73	0.8953 1.2898

A= Asymptomatic weight, B =scale parameter (constant), C=Relative growth rate, AIC=Akaike's Information criteria, R^2 =coefficient of determination, SD =Standard deviation, BW =Body weight BL=body length, TL =thigh length, SL =Shank length, WL = Wing length, CG =Chest girth, and CW=Chest width

Conclusions

The study showed that only body weight and length of male and female Noiler chickens differed and such differences were more obvious during the later growing phase with the male having higher values than the female. Though, both the Gompertz and Logistic models adequately described the growth of Noiler chickens (high R^2), the Gompertz was better when the other goodness of fit criteria; AIC and SD were considered. The Gompertz model is therefore recommended for describing growth of male and female Noiler chickens.

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