Modelling growth in seven chicken genotypes

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Abstract

Three non-linear growth models were used to fit weight-age data for seven chicken genotypes. Comparisons were made among these models for goodness of fit, biological interpretability and computational ease. Monomolecular and Richards Models overestimated body weight at the early phases of growth. All the three models underestimated the asymptotic mature weight but Gumpertz function gave a better estimate than the other two. Maturing rates were also variable and Richards Model gave the best estimate of K. Using these three non-linear models to describe growth rate of chest girth of the seven chicken genotypes yields a different result from that of the body weight. The point of inflection ranged from -3.56 for F/Na (F/Na) genotype to 28.26 for frizzled (Fr x Fr) genotype. Genetic variations in rates of gain, maturing rate and mature size were observed.

Keywords: Nonlinear, growth models, maturing rates, Genotypes

Introduction

Animal growth can be defined as the increase in size and changes in functional capabilities of the various tissues and organs of animals that occurs from conception through maturity. Growth curves reflects the lifetime interrelationship between an individual or genotypes inherent impulses to grow and mature in all body parts and the environment in which the impulses are expressed. Among the statistical procedures available for analyzing growth data are simple linear statistical model, non linear growth functions, the regression relationship between size and age and the orthogonal polynomials. The fitting of non linear functions for growth data offers an

opportunity to summarize the information contained in the entire sequence of size-age points into a small set of parameters that can be interpreted biologically and used to derive other relevant growth traits (Fitzhugh, 1976, Perotto *et al.*, 1992 and Ptak *et al.*, 1994).

Growth models like the logistic (LOG) (Pearl and Reed, 1923) Gompertz (GMP) (Winsor, 1932) Monomolecular (MON) (Brody, 1945, Von Bertalanffy (Von Bertalanffy, 1957) and Richards (1959) have been used extensively to describe the growth pattern of cattle, sheep and goat in the developed world.

Attempts had also been made to model the growth of cattle and goat genotype in Nigeria

(Ozoje, 1999). Little attention has been given to the possibility of modeling the growth of chicken genotypes in the Nigerian environment and generating data which can aid selection and genetic progress. Empirical descriptions of weight-age relationships in chicken will provide a technique for reducing the number of variables describing growth and characterising the form of growth. This research was therefore conducted to model the growth of seven chicken genotypes in the Nigerian environment using three non-linear models.

Materials and Methods

The growth data used in this study were obtained from the research conducted at the Poultry breeding unit, of the Teaching and Research farm of the University of Agriculture, Abeokuta, Ogun State between 1998 and 1999. The area lies in the south-western part of Nigeria and has a tropical climate with a mean annual rainfall of about 1037mm. The mean ambient temperature ranges from 28°C in December to 36°C in February with a yearly average of 34°C. Relative humidity ranges from 60% in January to 94% in August with a yearly average of about 82%. The population of indigenous and exotic chicken from which eggs were collected were randomly mated and largely unselected. They consists of both males and females of normal feathered, naked necked, frizzled feathered (indigenous strains) and two different exotic strains, a cross between frizzled and naked neck and also a cross between the exotic and indigenous strain gave rise to the sixth and seventh genotypes. Each breeding cock and associated hens were housed in separate pens in the same deep litter breeder house. The birds were individually wing-tagged for identification purposes. Trap nest was provided in each pen for oviposition and identification of which layer laid which egg. All chicks that resulted from each mating were properly identified and wing tagged.

All the chicks were subjected to the same standard methods of management at the brooder and growing phases. Body weight and body dimensions data were obtained from individual weekly body weight and chest girth measurements of two hundred and ninety six birds belonging to seven different genotypes from day old to twenty weeks (Table 1). Relevant aspects pertaining to experimental design, mating plans and flock management practices are detailed in the previous paper (Peters *et al.*, 2002).

Growth data for each genotype comprised a sequence of body weight (kg) and chest girth (cm) taken at day old through to 20 weeks of age on weekly basis. Increase in body weight (kg) and chest girth (cm) with respect to age is a genetically important measure of growth and body development.

The following functions were fitted to body weight-age and body dimension -age data.

1. (Gompertz) GMP $W_t = A e^{-be^{-kt}}$
2. (Monomolecular) MON $W_t = A(1 - be^{-kt})$
3. (Richards) RCD $W_t = A(1 - be^{-kt})^m$

where

W_t = weight (in grams) at age t (in weeks)

A, b, k, m = fitted parameters

e = base of natural logarithm

A = Asymptotic weight or average weight at maturity

k = rate of maturing (the larger the value of K , the earlier the animal matures)

b = constants of integration that expresses the rate at which a logarithmic function of W specific for each function changes with time

m = inflection point

SAS (1990) non-linear procedure (DUD method) was used to fit the functions. Residual mean squares, parameter estimate and converging of

Genotypes	No. of Obs.	Mono	Richards	Gumpertz
1. Normal (N x N)	45	1637.23	6.3746.85	1619.17
2. Naked neck (Na x Na)	42	54475.05	4474.53	767.86
3. Frizzled (Fr x Fr)	35	3736.02	52460.74	2831.50
4. Crossbreds	61	15198.04	94633.54	11850.76
5. F/Na (Fr x Na)	28	36171.10	36171.10	232.18
6. Exotic (OLY x BENA)	45	36390.24	15495.71	17085.96
7. Exotic (NP x BENA)	40	246947.48	249918.40	8915.14

interactive solution were used to compare the accuracy of prediction.

Results and Discussion

Body Weight

The MON and RCD functions overestimated the early weight of the seven chicken genotypes using residual mean squares to a large extent. The GOM functions gave a better estimate of the body weight of these genotypes generally (Table 1 and Figures 1-7). This result was contrary to reported works of Perotto *et al.* (1992), Ptak *et al.* (1993) and Menchasa *et al.* (1996). They all found that the RCD function gave the best fit in the breed of animals used for their investigations. Figures 1-7 showed the actual and predicted body weight of the seven chicken genotypes studied using the three growth models.

The GOM function also gave the best description of parameter A when compared to MON and RCD functions (Table 2). It is important to note that all the three growth functions underestimated

the asymptotic mature weight (Fig. 1-7). The estimate of B in GOM function is positive for all genotypes except genotype 7 (Exotic (NP x BENA) and gives a better picture than that of MON and RCD functions. Richards functions however, gave the best estimate of K which is the rate of maturing (the larger the value of K, the earlier the animal matures). From Table 2, the crossbreds (Progenies that arose from the cross of Exotic White Olympia cock and the indigenous normal feathered female, frizzled feathered female and the naked neck females had the highest value of K followed by (Fr x Na) genotype, frizzled, exotic (NP x BENA), normal (N x N), exotic (OLY x BENA) and then naked-neck (Na x Na). These results by implication means that the crossbred would mature earlier than the other chicken genotypes studied. This result revealed the expression of the indigenous genes in the crossbred genotype. Table 2 further revealed that the indigenous chicken genotypes had higher rate of maturing than their exotic

Fig. 1: Actual and predicted growth curve of normal feather indigenous chicken using three growth models.

Fig. 2: Actual and predicted growth curve of naked neck indigenous chicken using three growth models

Fig. 3: Actual and predicted growth curve of frizzled feathered indigenous chickens using three growth models

Fig. 4: Actual and predicted growth curve of crossbred chickens using three growth models

Modelling growth in chicken

Fig. 5: Actual and predicted growth curve of frizzled X naked neck chicken using three growth models

Fig. 6: Actual and predicted growth curve of W. Olypia X Bena Silver chickens using three growth models

counterpart. This fact can be partly attributed to the possession of major genes that assists in early adaptation to the environment. This was consistent with the report of Ibe (1992). He reported that frizzled and naked neck birds mature earlier than the normal feathered birds and that these genes could possibly be associated with sexual maturity.

Furthermore, the observed differences in the estimates of parameters A (asymptotic mature weight) for different genotype groups were in agreement with the growth characteristics of the examined strain of chicken. Exotic chickens grow to a heavier mature weight than their indigenous counterpart and therefore late maturing than their indigenous counterpart. Naked neck, frizzled and F/Na genotypes also had lower values than normal indicating that they have lower mature weight and also by implication mature faster than normal feathered individuals. The Richards model proposed by Richards (1959) is a four-parameter model with a variable inflection point M. The point of inflection is

where the estimated growth rate changes from increasing to a decreasing growth function. The M values of the various genotypes in this study with respect to body weight are variable as shown in Table 2. The frizzled feathered genotype had the highest value of M and followed by exotic NP x BENA), crossbred, naked neck (Na x Na), normal (N x N), exotic (OLY x BENA) and (Fr x Na) with corresponding values of 28.26, 10.65, 6.14, 5.09, 0.60 and -3.56 respectively. The variability of the point of inflection for the various genotypes also indicate the genetic variation inherent in the genotypes.

Chest girth

The chest girth taken as the circumference of the chest or breast muscle is a measure of growth and development. Growth involves both enlargement and development of an animal and includes both an increase in size and a change in body proportions. Development results from change in body proportions in response to changing function and cell cytology with age. It

Table 2: Means of estimated parameters of body weight for seven chicken genotypes using three growth models

Genotypes	Mono			Richards				Compertz		
	A	B	K	A	B	K	M	A	B	K
1. Normal (N x N)	-423.11	1.07	-0.05	-191.27	-0.28	7.43	5.09	61.80	0.61	-0.17
2. Naked-neck (Na x Na)	-1464.63	-0.14	534.69	-9.97	-0.72	-0.16	6.14	14.77	1.09	-0.19
3. Frizzled (Fr x Fr)	-87.83	1.48	-0.09	11.76	0.83	21.42	28.26	19.05	1.17	-0.16
4. Crossbreds	-2.84	-5.57	-0.13	-184.10	-0.14	119591.44	9.66	13.88	1.22	-0.22
5. F/Na (Fr x Na)	286.43	0.89	992.29	-80.39	0.89	5499.12	-3.56	18.67	0.95	-0.17
6. Exotic (OLY x BENA)	-17.73	-2.45	-0.14	-1220.07	1.16	-0.04	0.60	4.53	2.85	-0.20
7. Exotic (NP x BENA)	826.94	0.94	127.75	9.02	1.00	18.62	10.65	110.01	-0.87	0.05

is normally accompanied by an orderly sequence of maturational changes and involves accretion of protein and increases in length and size, not just an increase in weight (Gous, 1997). From the results (Table 3), it is interesting to observe that the values of the residual mean square when the three growth functions are compared did not follow similar pattern with that of body weight despite the fact that the same genotypes were involved. The Richards model gave a better description of the chest girth than the other two models though all the three models underestimated the values of the chest girth to a large extent. This result indicates that using the same growth model to describe different traits in a particular animal or genotype may not be appropriate.

The variability of values of A as indicated in Table 4 for chest girth indicates genetic variation

between the strains of chicken studied. The values of the constant of integration (B estimates) across all the strains as described by MON and RCD functions were closer than the values obtained when GOM function was used. The B estimate of the GOM function was almost the same for all the strains of chicken studied. The K estimates of the strains of chicken studied when MON and RCD functions were used as indicated in Table 4 were also the same for the first three genotypes on the table. The RCD function gave a higher estimate of K for crossbreds and F/Na (Fr x Na) than MON function for these strains. These variations in the results can be due to the same reason adduced by Gous (1997). He reported that growth and muscle development is a complex process affected by extrinsic, intrinsic and genetic factors. Hormonal influence was reported to be the most significant intrinsic factor and food supply the most extrinsic factor. Since

Table 3: Residual mean squares (RMS) of chest girth for the seven chicken genotypes using three growth models

Genotypes	Mono	Richards	Gompertz
1. Normal (N x N)	0.18	0.18	0.19
2. Naked-neck (Na x Na)	0.03	1.50	0.04
3. Frizzled (Fr x Fr)	1.37	1.53	0.09
4. Crossbreds	0.31	0.91	0.16
5. F/Na (Fr x Na)	0.08	1.86	0.01
6. Exotic (OLY x BENA)	34.91	0.88	0.20
7. Exotic (NP x BENA)	1.95	1.76	0.27

Table 4: Means of estimated parameters of chest girth for the seven chicken genotypes using three growth models

Genotypes	MODELS									
	Mono			Richards				Compertz		
	A	B	K	A	B	K	M	A	B	K
Normal (N x N)	18.25	0.68	0.03	30.42	0.68	0.03	0.06	79.06	0.05	0.01
Naked neck (Na x Na)	18.47	0.69	0.03	30.31	0.32	10.51	0.06	75.44	0.05	0.00
Frizzled (Fr x Fr)	19.14	0.30	7.24	99.20	0.08	0.07	0.07	76.49	0.05	0.00
Crossbreds	-0.54	3.27	0.03	-15.35	-0.07	-0.15	3.83	88.67	0.05	0.00
F/Na (Fr x Na)	13.85	0.56	0.08	-100.16	-0.09	19909.11	0.60	73.03	0.05	0.00
Exotic (OLY x BFNA)	2.85	0.22	0.14	26.49	0.54	0.09	0.60	132.71	0.04	0.05
Exotic (NP x BENA)	-17.54	1.18	-0.01	-42.15	-0.03	0.09	5.81	109.17	0.04	0.00

Fig. 7: Actual and predicted growth curve of Napri X Bena Silver chickens using three growth models

the birds were kept under the same conditions of housing, feeding and other management factors, the only factor that can then be responsible for the observed differences in the estimates as observed in the tables is intrinsic factor which consists of both the hormonal and the genetic factors.

Conclusion

It can be concluded from the findings of this research that more than one growth model is required to effectively describe the growth curve/pattern of various chicken genotypes. GOM function gave the best description of parameter A in body weight while the values given by MON and RCD functions were better than GOM function when the growth of chest girth was considered. It is therefore recommended that several growth models be compared to determine which one best fits the growth pattern of different chicken genotypes.

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