

Characterisation of local Ghanaian chickens: growth performance evaluation based on Richards growth model and genetic size scaling

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Accepted: 14 March 2011 / Published online: 1 April 2011
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Abstract The Richards growth model was fitted to body weight-age data of local and SASSO T44 chickens to describe their growth performance. Males had higher ($P < 0.05$) asymptotic mature weights than females. Within the local chicken population, birds from the savannah zone had higher ($P < 0.05$) asymptotic mature weights compared to forest chicken which ironically had higher body weights at hatch. Male local chicken had lower maturing rates compared to the females. Female local chicken were superior to SASSO T44 females in terms of maturing rate. On the average, local chickens took relatively longer time (78.4–83.3 days) to reach the point of inflection than the SASSO T44 population (74.2–79.8 days). However, there were no significant differences ($P > 0.05$) in the age at inflection among local chicken populations. The shape parameter for SASSO T44 chicken (0.053–0.370) and maturation rate for local chicken (0.177–0.198) were the most critical parameters. Scaling the body weights into degree of maturity highlighted the degree to which genotypes matured over time. Female chickens had the highest ($P < 0.05$) degree of maturity at all ages. The local chicken populations were also metabolically older than

SASSO T44 chickens. Results of this study provide an opportunity to develop breeding strategies for local chicken by modifying either management practices or their genetic makeup to positively affect their growth and productivity.

Keywords Local chicken · Richards growth model · Degree of maturity · Metabolic age

Introduction

Ghanaian local chickens are adapted to the tropics and represent a huge genetic resource of immense value to the livelihoods of many households (Osei-Amponsah 2010). However, little has been done to characterise local chickens either at the genetic or the phenotypic level in order to design appropriate breeding programmes for their sustainable use. In other countries, growth models have been used to determine optimum feeding regime, economic traits, optimum age at slaughter in chickens (Narinc et al. 2010; Faridi et al. 2011) and the effects of breed, sex and artificial selection (Aggrey 2003, 2009; Norris et al. 2007; Goto et al. 2010) on growth. Genotypes are associated with inherent size factors that determine the adult body sizes of animals. This in-built genetic factor operating throughout growth and estimated as adult body weight (Taylor 1980, 1985) has an important bearing on the efficiency of that particular genotype. Ali et al. (2002) recommended that both genetic and underlying size differences should be considered in breed comparisons.

Mathematical models describing growth kinetics are important tools to predict biological phenomena such as BW at a specific age, a maximum growth response and/or growth rates. Classical models such as Gompertz and Richards have been extensively used to describe broiler

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studies (Ahmadi and Golian 2008; Arnaud et al. 2008). The generalised growth curve model (Richards 1959) predicts growth rate, age at maximum growth, asymptotic weight and the trajectory of growth or growth pattern. This model encompasses the monomolecular ($n=-1$), Gompertz ($n=0$) and logistic ($n=1$) equations for particular values of parameter n . For the Richards model, the point of inflection occurs at any fraction of the mature weight, as n varies over the range $-1 < n < \infty$ (Darmani Kuhl et al. 2003). The Richards growth model is useful for growth analyses in ducks and other poultry like geese and chicken (Ahmadi and Golian 2008; Zhang et al. 2008). The objective of this study therefore was to use the Richards growth model to compare the growth performance of local Ghanaian chickens and the French free range SASSO T44 chickens as part of the phenotypic characterisation of the local poultry genetic resources in Ghana and conservation of Animal Genetic Resources in the tropics.

Materials and methods

Experimental birds and management

Ghana is a tropical country with its northern savannah zone between latitudes 8°30'N and 11°00'N of the equator and longitudes 2°30'W and 0°30'E of the Greenwich Meridian. The forest zone of Ghana lies between latitudes 4°75'N and 7°30'N of the equator and longitudes 3°00'W and 1°00'W of the Greenwich Meridian. Mean monthly temperatures at the Agricultural Research Centre range from 24.8°C in August to 28.3°C in February with a mean of 26.9°C. The source of experimental chickens and their management have been described by Osei-Amponsah (2010). Briefly, experimental chickens from the same ecozone (forest or savannah) were grouped into families comprising a cock and five hens and the collection of fertile eggs began a week later. All eggs were labelled and incubated artificially using table top incubators. The chickens from the two ecozones hatched around the same time. After hatching the chicks were separated into ecozones and reared on deep litter. Day-old chicks of the SASSO T44 breed were imported from France to serve as control. SASSO T44 was chosen because it is adapted to free range rearing in France like the savannah and forest chickens in Ghana.

Traits measured and growth curve modelling

The chicks were weighed at hatch then fortnightly until the 12th week and then monthly until the 40th week for the purpose of describing their growth. Some of the chickens died or were slaughtered prior to maturity for some carcass studies. As such, only the animals with sufficient data to be used in the Richards equation were used in this study. Data

for all individuals for whom the Richards equation could not be fitted were excluded in the analysis of all the traits in the present study. This explains the variation in the number of chickens used in the study (Table 1).

The Richards growth curve was used because it fitted the data well when different growth models were compared in an earlier study (unpublished). The Richards function is as follows:

$$W = \frac{W_0 W_f}{\left[W_0^n + (W_f^n - W_0^n) e^{-kt} \right]^{1/n}}$$

Where,

- W_f Is the upper asymptote
- k Is a decay constant and
- n Is the asymmetry parameter.

The mean hatch weight for the Genotype × Sex subclass was specified as the lower asymptote W_0 in order to get reasonable estimates for the other parameters. The growth parameters for each individual chicken were first estimated using Gauss–Newton algorithm. If there was no convergence within 1,000 iterations, then the Newton–Raphson algorithm was used. Chickens with non-convergence iterations by one of the two algorithms were excluded from further analysis, and were thus not used in this study.

The inflection point of the Richards growth equation was predicted at a weight W and time t as follows:

$$W = W_f [1/(n+1)]^{1/n}$$

$$t = -\ln \left\{ n W_0^n / (W_f^n - W_0^n) \right\} / k$$

In addition, growth performance indicators were calculated for each individual chicken as follows:

1. Relative growth rate, $RGR = \frac{dW}{dt} \times \frac{1}{W_i} \times 100$,
 $= [(\log \text{ end wt} - \log \text{ start wt}) \div \text{weeks on test}] \times 100$

Where, W is in g and t is in weeks.

Table 1 Number of female and male chickens from three genotypes used in the study

Genotype	Sex	Age (weeks)				
		At hatch	16	20	28	40
SASSO T44	Female	72	72	70	70	62
	Male	17	17	17	16	10
Forest	Female	113	113	109	96	89
	Male	103	103	102	68	39
Savannah	Female	66	66	63	58	56
	Male	90	89	85	55	54

Table 2 Least squares means (\pm standard errors) for Richards growth parameters^a of female and male Forest, Savannah and SASSO T44 chickens

Genotype	Sex	W_0 (g)	W_f (g)	k (weeks ⁻¹)	n
SASSO T44	Female	38.1a	3,076 \pm 4b	0.156 \pm 0.007d	0.053 \pm 0.038c
	Male	38.1a	3,352 \pm 8a	0.217 \pm 0.014a	0.370 \pm 0.077a
Forest	Female	26.5b	1,223 \pm 3f	0.196 \pm 0.006b	0.383 \pm 0.031a
	Male	26.9b	1,681 \pm 4d	0.177 \pm 0.006c	0.281 \pm 0.032b
Savannah	Female	25.1c	1,309 \pm 4e	0.198 \pm 0.008b	0.364 \pm 0.040a
	Male	26.2b	1,780 \pm 4c	0.184 \pm 0.006bc	0.279 \pm 0.034b

Where, W_0 is the lower asymptotic weight at $t=0$, W_f is the upper asymptote, representing mature body weight, k is a rate constant, and n is a shape parameter influencing point of inflection.

Within columns means followed by the different letters are significantly different ($P<0.05$)

$$^a \text{From the model: } W = \frac{W_0 W_f}{[W_0^n + (W_f^n - W_0^n)e^{-kt}]^{1/n}}$$

- Degree of maturity=Body weight $\div W_f$ (Fitzhugh and Taylor 1971)
- Metabolic age=Age in weeks $\div W_f^{0.27}$ (Fitzhugh and Taylor 1971)
- Growth rate (grams/week)=GR=(End weight–Start weight) \div (End age–Start age)
- Scaled growth rate=GR $\div W_f^{0.73}$ (Taylor 1980)

calculated for each pair of comparisons due to unequal numbers of animals per group. The mathematical modeling, trait derivations and statistical analysis were all done using GenStat Release 10 (Payne et al. 2007).

Results

Least squares means for Richards growth curve parameters of experimental chicken are as shown in Table 2. Overall, male chicken had higher ($P<0.05$) asymptotic mature body weights, W_f than females. Higher maturing rates, k were predicted for local female chicken (0.196–0.198 g/week) compared to the males (0.177–0.184 g/week) whilst for the SASSO T44 chicken the males rather had the highest average maturing rate (0.217 g/week). The shape parameter, n was higher in local females than males indicating that the females reached mature weight faster than the males. Weight at the point of inflection in the savannah male population was significantly higher ($P<0.05$) than the forest males (Table 3).

Statistical analysis

All traits were subjected to general linear model analysis to compare genotype by sex effects using the model:

$$y_{ijk} = \mu + g_i + s_j + gs_k + e_{ijk}. \text{Where}$$

- y_{ijk} Growth curve parameter
 g_i Effect of the i th genotype
 s_j Effect of the j th sex
 gs_k Interaction between genotype and sex.

The means were separated using the least significant difference method. The standard error of difference was

Table 3 Least squares means (\pm standard errors) of predicted^a body weight (grams) at the inflection point and selected ages of experimental chickens

Ecotype	Sex	Inflection point		Age (weeks)			
		Age (weeks)	Weight (g)	4	8	20	28
SASSO T44	Female	10.6 \pm 0.3b	1,124.0 \pm 12.7b	251.5 \pm 4.1a	727.9 \pm 11.6a	2,309.3 \pm 26.7b	2,750.3 \pm 31.6b
	Male	11.4 \pm 0.5ab	1,422.6 \pm 25.5a	210.9 \pm 8.1b	723.7 \pm 23.2a	2,825.9 \pm 53.4a	3,217.6 \pm 63.2a
Forest	Female	11.2 \pm 0.2ab	512.1 \pm 10.4e	111.1 \pm 3.3e	301.9 \pm 9.5c	990.3 \pm 21.9e	1,147.8 \pm 25.8e
	Male	11.7 \pm 0.2a	682.1 \pm 10.7d	127.0 \pm 3.4cd	366.2 \pm 9.7b	1,300.9 \pm 22.4d	1,552.3 \pm 26.5d
Savannah	Female	11.2 \pm 0.3ab	537.7 \pm 13.2e	116.5 \pm 4.2de	324.9 \pm 12.0c	1,054.4 \pm 27.7e	1,222.1 \pm 32.7e
	Male	11.9 \pm 0.2a	721.6 \pm 11.5c	132.4 \pm 3.7c	394.5 \pm 10.5b	1,377.9 \pm 24.1c	1,627.9 \pm 28.6d

Within columns means followed by the different letters are significantly different ($P<0.05$)

^a From the Richard's equation

Figure 1 shows the relative growth rate of male and female chickens. Irrespective of genotype or sex, relative growth rate dropped sharply from hatch to about 12 weeks and then gradually until the end of the study period. The relationship between degree of maturity and age of male and female chickens is as shown in Fig. 2. As might be expected, degree of maturity increased with age and reached an asymptote from the 28th week onwards. In general, female chickens were metabolically older than the males.

Relationships between actual age and metabolic age and between degree of maturity and metabolic age of male and female experimental chickens are as shown in Figs. 3 and 4, respectively. SASSO T44 chickens had higher degrees of maturity per metabolic age. Least square means for growth rate and scaled growth rate between selected ages of female and male chickens from three populations are as shown in Table 4. In general growth rates increased from hatch and 8 weeks and reached their peak between 12 and 20 weeks but declined between the 20th and 28th weeks. Scaling growth rates by metabolic weights affected growth rates in the first phase of the growth curve (0–8 weeks) with no significant differences between the sexes but with the SASSO T44 chicken still being superior to the local chicken. The results of the scaled growth rates for the two other periods considered (12–20 weeks and 20–28 weeks) were similar to those of the actual growth rates.

Discussion

The simultaneous consideration of both relative growth rate and absolute growth rate gives better information than

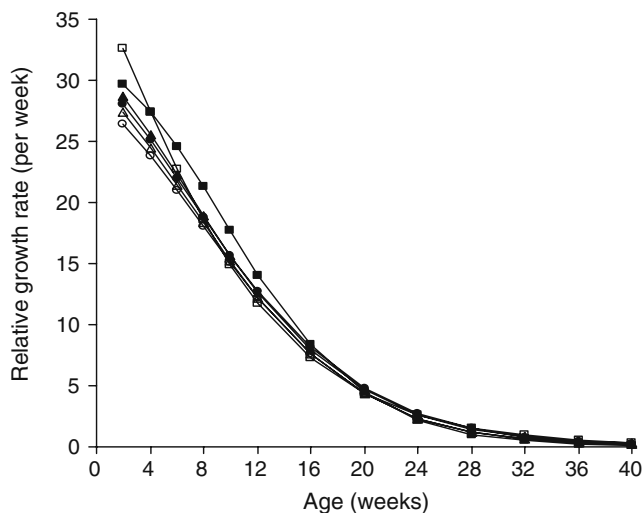


Fig. 1 Relative growth rate of male and female chickens from the SASSO T44 (black square male; white square female), Forest (black circle male; white circle female) and Savannah (black triangle male; white triangle female) chickens

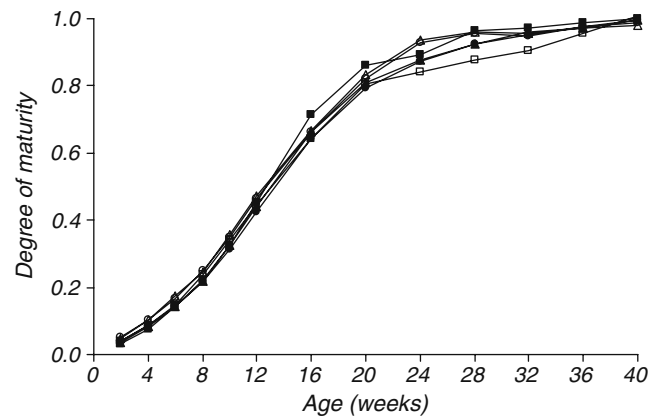


Fig. 2 Relationship between degree of maturity and age of male and female chickens from the SASSO T44 (black square male; white square female), Forest (black circle male; white circle female) and Savannah (black triangle male; white triangle female) ecotypes

examining only one of them to compare changes in growth (Aggrey 2003). Although there is no data on the growth performance of SASSO T44 chickens in Ghana, the average body weight of SASSO T44 in this study at 12 weeks was 1.5 kg compared to 2 kg at the same age in France (SASSO 2010) and this can be attributed to the effect of genotype-environment interaction. Differences between specific growth rates of local and SASSO T44 chicken in early part of developmental period may indicate correlated differences in asymptotic weight W_f (Sezer and Tarhan 2005). The forest and Savannah chicken like most tropical chicken are adapted to the local environment. Within the local chicken population, females had higher maturing rates but lower asymptotic mature weights W_f (Table 3) and this is because chickens which mature faster do not attain higher mature weights. It is generally expected that individuals with lower initial growth rate would reach the age of maximum growth sooner and, consequently

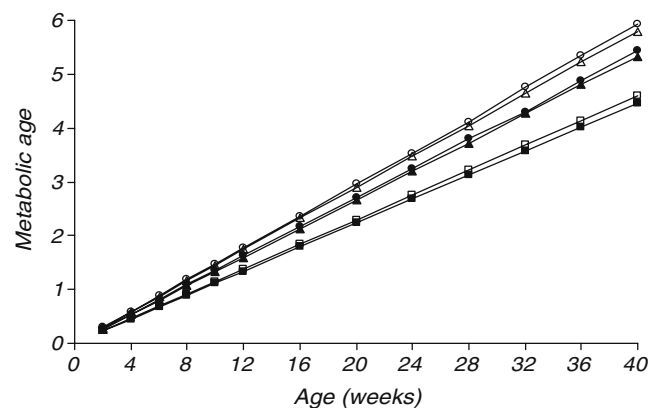


Fig. 3 Relationship between metabolic age and actual age of male and female chickens from the SASSO T44 (black square male; white square female), Forest (black circle male; white circle female) and Savannah (black triangle male; white triangle female) ecotypes

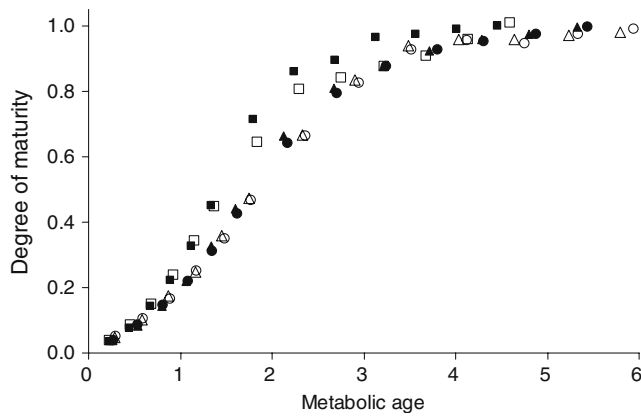


Fig. 4 Relationship between degree of maturity and metabolic age of male and female chickens from the SASSO T44 (black square male; white square female), Forest (black circle male; white circle female) and Savannah (black triangle male; white triangle female) ecotypes

show higher exponential decay k , than individuals with higher initial growth rate (Aggrey 2002). Overall, regardless of genotype, male chicken had higher adult body weights W_f , lower maturing rates and reached the point of maximum growth later than female chicken. This finding is in agreement with the results of Narinc et al. (2010) and Ali et al. (2002) who reported that irrespective of genotype or the rearing system, male birds had higher adult body weights W_f and lower maturing rates k . Such a negative correlation between W_f and k could be expected (Mignon-Grasteau et al. 2000) for the growth curves that have similar shape parameters because the rate of maturation together with the shape parameter determines the speed of the curve to reach the asymptotic body weight (Sezer and Tarhan 2005).

The range of estimated values of the maturing rate parameter k , for male chicken in the present study (Table 2) were higher than the 0.138 and 0.169 g/day estimated for male South African Venda and naked neck chickens (Norris et al. 2007). Values of the maturing rate parameter k , fell within the range reported for Athens–Canadian random-bred chickens (0.0224 g/day for males and 0.0216 g/day for females; Aggrey 2002); 0.031 g/day reported for label-type chickens (N'dri et al. 2006) but lower than the 0.036 g/day reported for male broiler chickens (Goliomytis et al. 2003) and 0.035 to 0.0371 g/day estimated for cockerels from six commercial strains (Hancock et al. 1995).

The shape parameter, n of the local male chickens were closer to zero than that of the indicating that the female growth curves look more like the Gompertz model rather than the logistic model. On the other hand, n parameters for females SASSO T44 chicken were closer to the Gompertz model than the logistic model (Sezer and Tarhan 2005). Brisbin et al. (1987) suggested that n has a greater propensity to change in response to environmental changes than the asymptotic weight or growth rate and may be used to study the effects of environmental stress on growth. The trajectory of growth as defined by n may also reflect the architecture of body composition and could therefore be used to manipulate the desired body composition (Aggrey 2002).

The position of the inflection point strongly influences the growth rate constant value k , and mature BW, W_f . Age and weight at the inflection point were estimated high for male populations in this study compared to the females. This extension of the acceleration time may also explain the increase in the estimated mature body weight W_f for the males (Sezer and Tarhan 2005). On the average, local

Table 4 Least squares means (\pm standard errors) for growth rate and scaled growth rate between selected ages of female and male Forest, Savannah and SASSO T44 chickens

Ecotype	Sex	Age (weeks)		
		0–8	12–20	20–28
Growth rate (g/week)				
SASSO T44	Female	83.7 \pm 1.4 ^b	137.6 \pm 2.1 ^b	27.0 \pm 2.6 ^b
	Male	90.3 \pm 3.0 ^a	171.6 \pm 4.1 ^a	40.9 \pm 5.3 ^a
Forest	Female	34.0 \pm 1.1 ^d	54.6 \pm 1.7 ^d	23.4 \pm 2.9 ^b
	Male	41.8 \pm 1.2 ^c	76.7 \pm 1.7 ^c	28.0 \pm 2.6 ^b
Savannah	Female	36.9 \pm 1.4 ^d	57.3 \pm 2.2 ^d	27.0 \pm 4.9 ^b
	Male	45.0 \pm 1.2 ^c	80.4 \pm 1.9 ^c	27.9 \pm 2.9 ^b
Scaled growth rate (g/unit mature body weight per metabolic week)				
SASSO T44	Female	0.242 \pm 0.005 ^a	0.393 \pm 0.007 ^b	0.073 \pm 0.010 ^b
	Male	0.243 \pm 0.012 ^a	0.458 \pm 0.013 ^a	0.109 \pm 0.019 ^{ab}
Forest	Female	0.191 \pm 0.004 ^b	0.306 \pm 0.006 ^d	0.126 \pm 0.011 ^a
	Male	0.187 \pm 0.005 ^b	0.340 \pm 0.006 ^c	0.123 \pm 0.010 ^a
Savannah	Female	0.196 \pm 0.006 ^b	0.305 \pm 0.007 ^d	0.131 \pm 0.018 ^a
	Male	0.191 \pm 0.005 ^b	0.345 \pm 0.006 ^c	0.116 \pm 0.011 ^a

Within columns means followed by the different superscripts are significantly different ($P < 0.05$)

chickens took relatively longer time (78.4–83.3 days) to reach the point of inflection than the SASSO T44 population (74.2–79.8 days). Aggrey (2002) estimated 63.4 and 59.8 days respectively for male and female Athens–Canadian random-bred chickens using the Richards model which were lower than estimates obtained in the present study. The range of ages at which chicken in the present study reach the point of inflection as predicted by the Richards growth model (74.2–83.3 days) compares favourably with the 79.8 and 81.5 days reported for White Leghorn and New Hampshire cockerels (Knížetová et al. 1991) but higher than the 44.4 days (Goliomytis et al. 2003) and 48.9 days (N'dri et al. 2006) estimated for male broilers, label-type chickens and White Leghorns, respectively, which all however used the Gompertz model. Generally, purebreds and unselected populations take a relatively longer time to reach the point of maximum growth or inflection than broilers and random-bred chickens due to the different genetic constitutions (Goliomytis et al. 2003).

Scaling the body weights into degree of maturity highlighted the degree to which genotypes matured over time (Table 4). ANOVAs for degree of maturity at 8, 20 and 28 weeks of age revealed no significant ($P>0.05$) differences for genotype but there was a significant ($P<0.05$) effect of sex of chicken. Interaction between genotype and sex of chicken however did not have a significant ($P>0.05$) effect on the degree of maturity of chicken. Female chickens had the highest degree of maturity at all ages. This finding is in agreement with those of Ali et al. (2002) who found female chicken more matured at all ages than their male counterparts irrespective of the genotype or rearing system.

The local chicken populations were also metabolically older than SASSO T44 chickens due to the relatively lower asymptotic weights of local chicken. Plots of the relationships between degree of maturity and age of experimental chicken are as shown in Fig. 3. From these plots the use of Taylor's scaling rules (Taylor 1980) reduced substantially the magnitude of differences between the local genotype and SASSO T44 chicken. This confirms the findings of Ali et al. (2002) in which scaled curves tend to converge towards a narrow range of values for the entire growing period, suggesting an important role of the size influences in growth comparisons between genotypes. Furthermore, irrespective of genotype, female chicken were metabolically older than their male counterparts (Fig. 3) which is directly related to their relatively lower asymptotic mature weights. Finally, local chicken compared favourably with SASSO T44 chicken in terms of the relationship between their degree of maturity and metabolic age (Fig. 4) as a result of Taylor's scaling rules (Taylor 1980).

Conclusion

The Richards growth curve model adequately described the growth curves of local Ghanaian and SASSO T44 chicken. Regardless of genotype, male chicken had higher adult body weights, lower maturing rates and reached the point of maximum growth later than female chicken. Local chicken compared favourably with SASSO T44 chicken in terms of the maturing rate parameter and the age at which they attain maximum age. However, the local chicken were inferior in predicted mature body weights as they have not been selected for faster growth. The results of this study provide an opportunity to develop breeding strategies by modifying either management practices or genetic makeup of local chicken in order to positively affect their growth and productivity. Selection within local chicken populations for instance can help improve on their growth curve parameters by reducing the time taken by the birds to reach the point of maximum growth, increase maturing rate and ensure local chicken farmers make profit as relatively heavier mature birds will be marketed.

Acknowledgements Appreciation is expressed to the DURAS Project for permission to use data and the University of Ghana Graduate Fellowship programme for award of fellowship to R. Osei-Amponsah.

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