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ESTIMATION OF MODEL PARAMETERS OF THE JAPANESE QUAIL GROWTH CURVE USING GOMPERTZ MODEL

ESTIMACIÓN DE CURVAS DE CRECIMIENTO DE CODORNIZ JAPONESA UTILIZANDO EL MODELO GOMPERTZ

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ADDITIONAL KEYWORDS

Asymptotic weight. Growth. Maturity rate.

PALABRAS CLAVE ADICIONALES

Coeficiente de madurez. Crecimiento. Peso asintótico.

SUMMARY

This study was conducted to describe the growth pattern of Japanese quails with the Gompertz growth model using body weight measurements from an unselected, random bred quail population. The coefficient of determination (R^2) was high for both male and female (0.98) indicating that the growth curves of the observed data were adequately described by the Gompertz model. However, male and female Japanese quails did not have identical growth patterns. Generally, females appeared to be heavier than males at all ages and this difference increased with age. Both male and female Japanese quail were 4 % mature at hatch but reached 98 and 96 % respectively, of their mature weights at 12 weeks of age. Thus, males matured faster than females though the latter had higher weights. Asymptotic weight (A) was higher (p<0.05) in females (168.83 g) than males (132.71 g) as was the case with integration constant (B). In contrast, maturity rate (k) was higher (p<0.05) in males (0.3765) compared to females (0.3262). Thus, a strong and negative relationship (–0.7981 and –0.8498 for male and female respectively) between maturation rate and asymptotic weight was observed. Age, weight and maximum gain at point of inflection for male and female Japanese quails were 2.48 *vs.* 2.91 weeks, 48.82 *vs.* 62.11 g and, 18.38 *vs.* 20.26 g respectively. Males reached the inflection point at a significantly (p<0.05) earlier age than females. Similarly, they had lower inflection weight and gain than female quail. And it explains difference between males and females Japanese quail in Nigeria.

RESUMEN

Este estudio fue realizado para describir el crecimiento de la codorniz japonesa, mediante el modelo de Gompertz, empleando medidas del peso corporal, tomadas al azar, de una población no seleccionada de codornices. El coeficiente de determinación (R^2) fue elevado (0,98) tanto para machos como para hembras, indicando que las curvas de crecimiento generadas con los datos obtenidos fueron adecuadamente descritas empleando el modelo de Gompertz. Sin embargo, los modelos de crecimiento de las codornices machos y hembras, no son iguales. Generalmente las hembras parecen más pesadas que los machos a cualquier edad y esta diferencia se incrementa con la edad. Tanto los machos como las hembras de codorniz japonesa estaban al 4 % de su madurez al nacimiento, pero alcanzaron, respectivamente, el 98 y 96 % de sus pesos maduros a las doce semanas de edad. Es decir, los machos maduraron más rápidamente que las hembras aunque éstas tenían pesos más elevados. El peso asintótico (A) fue más alto (p<0,05) en las hembras (168,83 g) que en los machos (132,71 g), lo mismo sucedió con la constante de integración (B). En contraste, la tasa de maduración (k) fue mayor (p<0,05) en los machos (0,3765) que en las hembras (0,3262). Así, se observó una fuerte correlación negativa (–0,7981 y –0,8498 para machos y hembras respectivamente) entre la tasa de maduración y el peso asintótico. La edad, peso y ganacia máxima en el punto de inflexión para machos y hembras de codorniz japonesa fueron: 2,48 *vs.* 2,91 semanas; 48,82 *vs.* 62,11 g y 18,38 *vs.* 20,26 g, respectivamente. Los machos alcan-

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zaron el punto de inflexión a edad más joven (p<0,05) que la de las hembras. De modo similar mostraron menor peso de inflexión y ganancia que las hembras. Ello explica las diferencias entre codornices japonesas machos y hembras en Nigeria.

INTRODUCTION

Quail farming is generating considerable interest in many parts of the world as it provides low energy/high protein meat of immense biological value. It also offers an excellent opportunity for poultry farmers to enter a new and profitable poultry business especially in Nigeria where it was only recently introduced. In addition to its lean meat, the egg is lower in cholesterol as compared to chicken (Musa *et al.,* 2008). They are, particularly, important for egg production in Japan and South East Asia and meat production in Europe (Minvielle, 1998).

Growth curves are useful tools representing the evolution of body weight during growth and are particularly important in breeding and management. In addition, curve parameters provide information on growth characteristics. Ricklefs (1985) pointed out that the purpose of curve fitting is to describe the course of mass increase with age by simple equations with few parameters. Growth curves can be used for pre-selection of animals as it provides prediction of future growth at any age. Brody (1945) suggested that the asymptotic or mature weight, rate of attainment of mature weight and the standardized age at which an animal attained the inflection point of the curve are parameters that could be manipulated by geneticists.

Different mathematical growth models have been used to define growth curves. The most commonly used functions to estimate animal's growth have three to four parameters. These include: Brody (Brody 1945), Bertalanffy (Bertalanffy, 1957), Richards (Richards, 1959), Logistic (Nelder, 1961) and Gompertz (Laird, 1965). Ratkowsky (1983) observed that these curves start at some fixed point, growth rate then increases up to an inflection point after which it decreases asymptotically to a final value. The growth of most galliforms including poultry conforms closely to the shape of the Gompertz. It is a three parameter growth function with a smooth sigmoid behavior and fixed point of inflection that has been cited as the model of choice for poultry data because of its overall fit and biological meaning of the model parameters (Anthony *et al*., 1991; Ricklefs, 1985; Akbas and Oguz, 1998; Narinc *et al*., 2010). The three parameters of the Gompertz growth model are defined as asymptotic weight (A), integration constant (B) and rate of maturity (k) (Akbas and Oguz, 1998). Kníztová *et al*. (1991) and Freitas (2005) found that Gompertz function excellently described broiler growth. In addition, Mendes (2009) observed that the Gompertz model had better fit to weight-age, shank width-age, shank length-age, body length-age data than other models. Similarly, Narinc *et al*. (2010) reported the Gompertz as the best model for Japanese quails when 11 growth models were compared. Wiseman and Lewis (1998) also employed the Gompertz to study the patterns of growth of live weight and carcass components in broilers. Since the Gompertz model generally fits the growth of many mammals and chickens (Hurwitz *et al*., 1991), the aim of this study was to describe growth of the Japanese quail from 0 to 12 weeks of age using the Gompertz curve.

MATERIALS AND METHODS

The study was carried out at the Poultry Unit of the University of Maiduguri Livestock Teaching and Research Farm, Maiduguri, Borno State, Nigeria. Maiduguri, the Borno State capital is situated on latitude 11°5' N, longitude 13°09' E and at an altitude of 354 m above sea level. The area falls within the Sahelian region of West Africa, which is noted for great climatic and seasonal variations. It has very short period (3-4 months) of rainfall of 645.9 mm/annum with a long dry season of about 8-9 months. Relative humidity is 45 % in August which usually lowers to about 5 % in December and January. Day length varies from 11 to 12 hours.

One hundred and twenty one (54 male and 67 females) Japanese quails hatched from eggs collected from unselected and random mating parents were used for the study. After hatching, the chicks were individually weighed and labeled before brooding for two weeks. Hatched chicks were fed commercial broiler starter ration containing 23 % crude protein and 3000 kcal/kg of metabolizable energy to 6 weeks of age, then breeders diet containing 18 % crude protein and 2800 kcal/kg of metabolizable energy. The birds were housed at three weeks in cages (30x30x45 cm; with 2 birds per cage) and had free access to feed and water. Birds were weighed weekly from week 0 to week 12.

The Gompertz model was fitted to the quail growth data using Levenberg-Marquardt nonlinear least-squares algorithm in Statistix 9.0 and curve parameters obtained subjected to analysis of variance (ANOVA). Significant means were separated by Least Significant Difference (LSD). Goodness of fit for each model was determined by the following statistics; Coefficient of Determination (R^2) and Mean Square Error (MSE). R^2= 1"(SSE/ SST), where SSE is sum of square of errors and SST; total sum of squares. The Gompertz non linear model fitted to the body weight data was described by Ricklefs (1967) as:

$$Y_t = A \exp(-B\exp(-kt))$$

where:

Y_t= is the body weight (g) of birds at t weeks of age (t= 0, 1,…, 12);

A, B and k= are model parameters: A is asymptotic weight when time goes to infinity; B is a scaling parameter (constant of integration), which is related with initial values of Y, k is relative growth rate and e is eulerian number or base of natural logarithm (2.71828).

Weight and age at the inflection point (POI) were calculated as:

Y_I= A/e and t_I= B/k, respectively, while

Table I. *Means, standard deviation and degree of maturity (DMAT) for body weights at different ages (weeks) of the Japanese quail.* (Medias, desviación estándar y grado de maduración (DMAT) para el peso corporal a diferentes edades (semanas) en codornices japonesas).

	Male		Female		Overall
Age	Mean±SD	DMAT (%)	Mean±SD	DMAT (%)	Mean±SD
0	5.55±0.78	4.18	6.15±1.00	3.64	5.87±0.95
1	14.84±1.85	11.19	16.46±2.65	9.75	15.70±2.44
2	45.53±5.62	34.31	50.48±7.82	29.90	48.15±7.28
3	69.33±8.57	52.24	76.88±11.96	45.54	73.32±11.12
4	76.02±9.37	57.28	84.37±13.22	49.97	80.43±12.26
5	86.19±11.41	64.95	97.18±12.21	57.56	92.00±13.02
6	94.79±13.51	71.43	109.62±11.35	64.93	102.63±14.43
7	107.10±13.17	80.70	127.37±12.54	75.44	117.81±16.33
8	118.12±12.89	89.01	141.63±13.21	83.89	130.54±17.55
9	123.71±13.39	93.22	147.31±19.19	87.25	136.18±20.42
10	123.22±18.33	92.85	151.80±13.22	89.91	138.33±21.30
11	131.02±14.16	98.72	159.62±13.37	94.54	146.13±19.82
12	130.72 ±21.98	98.50	162.11±12.48	96.02	147.31±23.56

maximum weight gain at inflection point U_i= A·k/e and Degree of maturity (DM)= Y_t/A.

RESULTS AND DISCUSSION

Descriptive statistics and degree of maturity for body weights at different ages of male and female Japanese quails are presented in **table I**. Generally, females appeared to be heavier than males at all ages and this difference increased with age. Similarly, the SD also increased with age as is common with time series data (Aggrey 2002; Nahashon *et al*., 2006). Many authors also reported that sexual dimorphism was in favour of females in the Japanese quail (Aggrey and Cheng, 1994; Aggrey *et al*. 2003; Kızılkaya *et al*., 2004). They observed that male and female Japanese quails do not have identical growth patterns as is evident in **figure 1**. The curves however showed good fit of the data by the Gompertz model for both male and female Japanese quails with a characteristic S shape as has previously been reported (Kızılkaya *et al*., 2006). They however over and under estimated early weights (0-6 weeks) of the quails with little difference between observed and predicted weights thereafter. This also agrees with the reports of Brown *et al.* (1976). Both male and female Japanese quail were 4 % mature at hatch but reached 98 and 96 % respectively, of their mature weights at 12 weeks of age. Thus, males matured faster than females though the latter had higher mature weight. This result may be important in determining the length of commercial breeding for meat in the Japanese quail. It may also indicate the period of collection of growth data for analysis.

Estimated coefficients for the Gompertz model parameters of the Japanese quail are presented in **table II**. The coefficient of determination (R^2) was high for both male

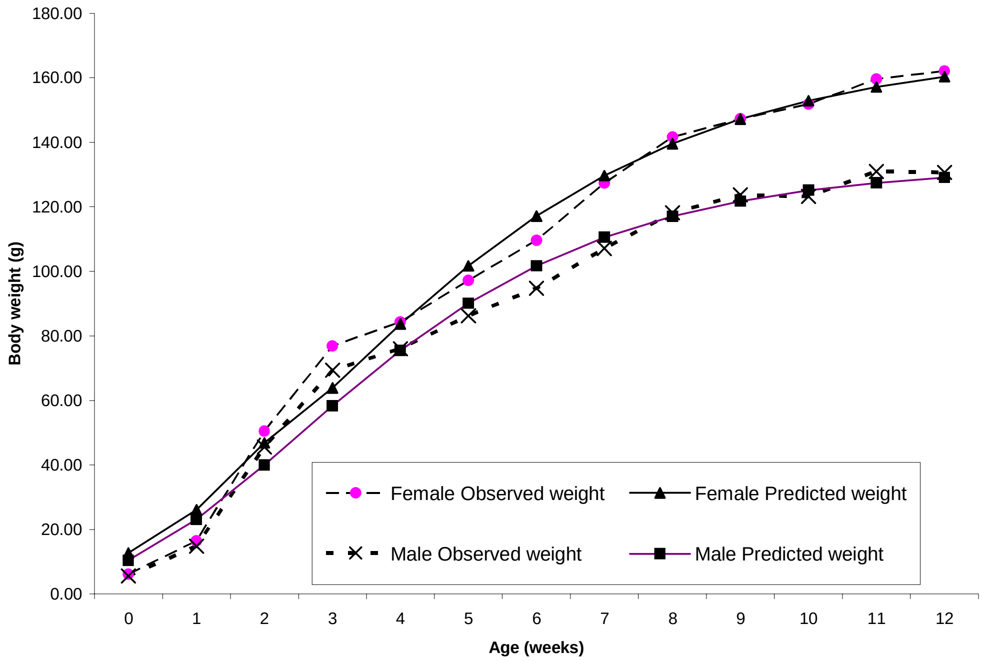

***Figure 1.** Observed and predicted growth curves for male and female Japanese quails*. (Curvas de crecimiento observada y estimada para machos y hembras de codorniz japonesa).

and female (0.98). This implies that the growth curves of the observed data were adequately described by the Gompertz function. This agrees with the reports of Akbas and Oguz (1998) and Balcıoglu *et al*. (2005). Asymptotic weight (A) was higher in females (168.83 g) than males (132.71 g). Differences in A between genders have been reported in the Japanese quail (Akbas and Oguz, 1998; Aggrey *et al*., 2003; Kızılkaya *et al*., 2004). The asymptotic weights for male and female Japanese quail in this study were lower than 189.0 and 239.0 g and, 177.12 and 218.51 g reported by Balcıoglu *et al*. (2005) and Kızılkaya *et al*. (2006). However, Narinc *et al*. (2010) observed that asymptote weight is directly related with genotype and environmental effects. Thus, quails fed in different environment and have different genotype will have different asymptotic weight. Asymptotic weights from different studies should therefore be compared with caution. Higher asymptotic weight in females has also been reported in the pearl gray guinea fowl (Nahashon *et al*., 2006). It was however higher for males in chicken (Aggrey, 2002).

Like the asymptote weight, B parameter (integration constant) which is related to initial weight (hatch weight) was higher in females than males. This agrees with the report of Kızılkaya *et al*. (2004) and Balcıoglu *et al*. (2005) but disagrees with those of Akbas and Oguz (1998) and Akbas and Yaylak (2000). These authors reported higher values for males than females.

However, parameter k (maturation or growth rate) was higher in males (0.3765) compared to females (0.3262). Similar observation was made by Akbas and Oguz (1998), Kızılkaya *et al*. (2004) and Balcıoglu *et al*. (2005). Parameter k indicates the rate of maturity and high values imply shorter periods of growth (early maturity) and lower mature weights. Thus, male quails grew faster than females and reached their weight at point of inflection and asymptotic weight at a younger age. Similar observation was made by Akbas and Yaylak (2000) and Kızılkaya *et al*. (2006). The estimates of correlation (–0.7981 and –0.8498 for male and female respectively) between parameters A and k showed a strong negative relationship between maturation rate and asymptotic weight. Thus, there seems to be an antagonistic relationship between asymptotic weight and growth rate since females with higher asymptotic weight had lower growth rate and were late maturing while the reverse was observed with males. Negative correlation between parameters A and k for Japanese quails has also been

Table II. *Estimated coefficients (±SE) and confidence limits (CL) for the Gompertz model parameters of the Japanese quail.* (Coeficientes (±SE) y límites de confianza (CL) para los parámetros del modelo Gompertz de la codorniz japonesa).

Model parameters	Male	CL (95 %)	Female	CL (95 %)
A	132.71±1.41	129.93-135.49	168.83±1.7121	165.47-172.19
B	0.9338±0.03	0.8676-1.000	0.9507±0.02	0.9037-0.9977
K	0.3765±0.01	0.3504-0.4026	0.3262±0.01	0.3082-0.3442
R^2	0.98	-	0.98	-
MSE	182.04	-	176.97	-
Inflection age (weeks)	2.48	-	2.91	-
Inflection weight (g)	48.82	-	62.11	-
Maximum weight gain at inflection point (g)	18.38	-	20.26	-
Correlation (A&k)	-0.7981		-0.8498	

reported (Akbas and Yaylak, 2000; Kızılkaya *et al.*, 2004, 2006).

Age, weight and maximum gain at point of inflection for male and female Japanese quails were 2.48 *vs.* 2.91 weeks, 48.82 *vs.* 62.11 g and, 18.38 *vs.* 20.26 g respectively. Males reached the inflection point at a significantly ($p<0.05$) earlier age than females. Similarly, the inflection weight and maximum gain was higher for female quails than males. Balcıoglu *et al.* (2005) and Kızılkaya *et al.* (2006) also reported higher inflection age and weight for female quails than males. In this study, females reached inflection age three days later than males. Du Preez and Sales (1997) reported that this delay was likely to arise from the higher asymptotic value and consequently the longer growth period. However, the inflection age (weeks) and weight (grams) reported for male and females respectively, in this study were lower than 2.55 and 69.0 and, 3.07 and 87.9 by Balcıoglu *et al.* (2005) and 3.30 and 92.83 and, 3.71 and 110.06 by Kızılkaya *et al.* (2006). The higher values reported in these studies could be because the authors obtained higher asymptotic weights for quails in their respective studies.

CONCLUSION

The Gompertz model adequately described the growth of both male and female Japanese quails though the pattern of growth differed. Male and female Japanese quails had almost attained their mature weights at 12 weeks of age. The males matured much earlier than females, but had lower asymptotic weights and gain at inflection point. Finally, understanding the growth pattern of the Japanese quail will contribute to efforts at improving this species in Nigeria.

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